

THE UNIVERSITY
OF ILLINOIS
LIBRARY

630.7

Oh3r

v.29

cop. 2



Digitized by the Internet Archive
in 2016

Twenty-ninth Annual
Report

OF THE

Ohio Agricultural Experiment Station

For the Year ending June 30, 1910

Published by order of the State Legislature

688.
Chas
V. 29
copy

OHIO AGRICULTURAL EXPERIMENT STATION

BOARD OF CONTROL

JOHN COURTRIGHT, <i>President</i>	Ashville
HENRY L. GOLL, <i>Secretary</i>	Swanton
D. L. SAMPSON, <i>Treasurer</i>	Cincinnati
GEORGE E. SCOTT	Mt. Pleasant
JOSEPH D. GUTHERY	Marion

STATION STAFF

CHARLES E. THORNE, M. S. A., *Director*

DEPARTMENTAL ORGANIZATION

Administration

THE DIRECTOR, *Chief*
WILLIAM H. KRAMER, *Bursar*
MARY M. LEE, *Stenographer*
F. W. GLASS, *Printer*
DORA ELLIS, *Mailing Clerk*
GLEN HALL, *Engineer*

Agronomy

C. G. WILLIAMS, *Chief*
F. A. WELTON, B. S., *Assistant*
WILLIAM HOLMES, *Farm Foreman*
C. A. PATTON, *Asst. Foreman, Meteorologist*
E. C. MORR, *Clerk*

Animal Husbandry

B. E. CARMICHAEL, B. S., *Chief*
J. W. HAMMOND, M. A., *Assistant*
GEO. R. EASTWOOD, B. S., *Assistant*
W. J. BUSS, *Clerk*

Botany

AUGUSTINE D. SELBY, B. S., *Chief*
TRUE HOUSER, *Assistant*
E. G. ARZBERGER, A. M., *Assistant*
W. O. GLOYER, A. M., *Assistant*
P. A. DAVIS, B. S., *Assistant*
FRED K. MATHIS, *Clerk*

Chemistry

JOHN W. AMES, M. S., *Chief*
E. W. GAITHER, B. S., *Assistant*
GEORGE BOLTZ, *Assistant*
MARY ADAMS, *Clerk*

Cooperation

L. H. GODDARD, C. E., *Chief*
M. O. BUGBY, B. S., *Assistant*
GAIL T. ABBOTT, A. B., *Assistant*
W. A. LLOYD, B. S., *Assistant*
W. M. COOK, A. B., *Assistant*
W. L. ELSER, B. S., *Assistant*
ORPHA M. KOONTZ, *Clerk*

Dairying

THE DIRECTOR, *Chief*
RALPH E. CALDWELL, B. S., *Assistant*
E. F. TIMMERMAN, *Butter Maker*
ANTHONY RUSS, *Herdsman*

Entomology

H. A. GOSSARD, M. S., *Chief*
J. S. HOUSER, B. S., *Assistant*
W. H. GOODWIN, B. S., *Assistant*
R. D. WHITMARSH, B. S., *Assistant*

Forestry

EDMUND SECRESO, B. S., *Chief*
J. J. CRUMLEY, Ph. D., *Assistant*

Horticulture

W. J. GREEN, *Vice Director, Chief*
F. H. BALLOU, *Assistant*
ORA FLACK, *Foreman of Orchards*
W. E. BONTRAGER, *Foreman of Grounds*
CHAS. G. LAPIER, *Foreman of Greenhouses*

Nutrition

E. B. FORBES, Ph. D., *Chief*
A. C. WHITTIER, B. S., *Assistant*
R. C. COLLISON, M. S., *Assistant*
M. HELEN KEITH, A. M., *Assistant*

Soils

THE DIRECTOR, *Chief*
R. C. E. WALLACE, B. S., *Field Assistant*
THOS. F. MANNS, M. S., *Soil Bacteriologist*
EDWARD MOHN, *Supt. Test-farm, Strongsville*
LEWIS SCHULTZ, *Supt. Test-farm, Carpenter*
HENRY M. WACHTER, *Supt. Test-farm, German?oww*

REPORT OF THE BOARD OF CONTROL

To His Excellency, JUDSON HARMON, Governor of Ohio:

SIR: I have the honor of submitting herewith the twenty-ninth annual report of the Ohio Agricultural Experiment Station, for the year ended June 30, 1910.

STATE APPROPRIATIONS

The following sums were appropriated by the last General Assembly for the support of the Station during the current fiscal year:

For Department of Administration.....	\$26,300
“ “ “ Agronomy.....	16,475
“ “ “ Animal Husbandry.....	15,000
“ “ “ Botany	10,900
“ “ “ Chemistry.....	3,700
“ “ “ Cooperative Experiments.....	20,470
“ “ “ Dairy Husbandry.....	8,000
“ “ “ Entomology.....	5,000
“ “ “ Forestry	10,000
“ “ “ Horticulture	10,950
“ “ “ Nutrition	4,000
“ “ “ Soils.....	10,500
“ Furniture and Carpets.....	500
“ Improvement of Road	500
“ Completing Nutrition Building.....	17,000
“ Extension of Power House.....	3,000
“ Purchase of land.....	4,000
Total.....	\$166,295

These appropriations provide for extension of work along several lines, including the establishment of a new department, that of Dairy Husbandry, the need for which was emphasized in our last annual report. This department will be organized at once.

The appropriations provide for the completion of the building for the work of the Department of Nutrition, for which an appropriation of \$5,000 was made by the previous Assembly. This building will include an abattoir and cold storage facilities of sufficient extent to accommodate the Departments of Animal Husbandry, Dairy Husbandry and Horticulture, as well as that of Nutrition.

Three thousand dollars is provided for extension of the Power House and four thousand for the purchase of land, which will be expended in the purchase of a lot near the Station grounds on which stands a large dwelling which will be used temporarily for office purposes, the present offices having become so crowded that additional room for this purpose is absolutely necessary. This dwelling is, of course, ill adapted to office purposes, while it is urgently needed by the Station for residence purposes, as is shown by the fact that of the 70 persons employed in the Station offices, 60 are compelled to find homes in town, from one to two miles from their work. This, of course, would not be a serious matter if there were a street car line with frequent service between the Station and town, but there is no such line. The Station now owns seven dwellings on the central farms, which are rented to employes at rates that bring in a fair interest on their value. It could use two or three times this many with a saving to the State much more than equivalent to their rental value. The most urgent need of the Station, however, is for larger office and laboratory facilities, and we renew our request for the following buildings:

1. An addition to the administration building, to provide new quarters for the Department of Agronomy, Horticulture and Forestry, and to permit the extension within the present building of the botanical and entomological laboratories. This addition will necessarily be built of stone and in fireproof construction.

2. A chemical laboratory of sufficient capacity to bring under one roof the two laboratories now in operation, thus facilitating economy in equipment and operation, and releasing the present rooms for other purposes to which they are better adapted and for which they are much needed. The laboratory should be of fireproof construction.

THE GERMANTOWN TEST FARM

In the spring of 1902 provision was made by the General Assembly in the appropriations to the Experiment Station for the establishment of a sub-station or test farm, to be located in the Miami Valley, and to have as one of its chief lines of work the study of problems relating to the culture of tobacco.

The Board of Control visited this region and selected a tract of 53 acres, lying less than a mile east of Germantown, Montgomery county, and since included within the corporate limits of that municipality. This tract was purchased by the President of the Tobacco Growers' Union, of Germantown, and leased to the Experiment Station for ten years at an annual rental of six percent on the purchase price, giving the Station the option of taking over the land at any time during the 10-year period on payment of the original purchase price.

This land proves to be admirably adapted to the work, and the experiments which were begun on it in 1903, and which include not only the culture of tobacco, but also of corn, wheat and clover, are yielding results of very great value to the agriculture of that region. As the option on this land will expire September 30th, 1912, and as the land is now worth much more than the option price, this option should be closed and the land purchased by the State.

Work of this kind is cumulative in character. One season's results, standing alone, have but little value; a number of seasons, with their varying climatic conditions, must be passed through before conclusions can safely be drawn, and even after 10 years' work it is to be expected that succeeding seasons will bring new developments, as is already being shown in the older tests at the Central Station. To discontinue this work now, therefore, would mean the loss of a large part of what has been accomplished.

COUNTY EXPERIMENT FARMS.

A bill introduced by Hon. George M. Wilber, of Union County, has become a law in the following form:

AN ACT

To supplement section 1165 by the enactment of sections 1165-1, 1165-2, 1165-3, 1165-4, 1165-5, 1165-6, 1165-7, 1165-8, 1165-9, 1165-10, 1165-11, 1165-12 and 1165-13 to authorize the establishment of county experiment farms.

Be it enacted by the General Assembly of the State of Ohio:

SECTION 1. That section 1165 of the General Code be supplemented by the enactment of sections 1165-1, 1165-2, 1165-3, 1165-4, 1165-5, 1165-6, 1165-7, 1165-8, 1165-9, 1165-10, 1165-11, 1165-12 and 1165-13 to read as follows:

Sec. 1165-1. In order to demonstrate the practical application under local conditions of the results of the investigations of the Ohio Agricultural Experiment Station, and for the purpose of increasing the effectiveness of the agriculture of the various counties of the state, the commissioners of any county in the state are hereby authorized and empowered to establish an experiment farm within such county as hereinafter provided for.

Sec. 1165-2 The experiment farms established under this act shall be used for the comparison of varieties and methods of culture of field crops, fruits and garden vegetables; for the exemplification of methods for controlling insect pests, weeds and plant diseases; for experiments in the feeding of domestic animals and in the control of animal diseases; for illustrations of the culture of forest trees and the management of farm woodlots; and for the demonstration of the effects of drainage, crop rotation, manures and fertilizers, or for such part of the above lines of work as it may be practicable to carry on.

Sec. 1165-3. Upon the filing of a petition with the county auditor signed by not less than five per cent. of the electors, based upon the vote for governor at the last preceding election, residing within the county, the commissioners of

such county shall submit to the qualified voters of such county a proposition to establish an experiment farm within such county, and to issue notes or bonds for the purchase and equipment of such farm, such proposition to be voted upon at the next general election following the receipt of the petition by the commissioners. Notice of the intention to submit such proposition shall be published by the county commissioners in two newspapers of opposite politics printed and of general circulation in said county, for at least four weeks prior to the election at which the proposition is to be voted upon, together with a statement of the maximum amount of money which it is proposed to expend in the purchase and equipment of such farm.

Sec. 1165-4. The county auditor shall file a written request with the board of deputy supervisors of elections asking for the preparation of the necessary ballots, which ballots shall be separate and apart from all other ballots, and which ballots shall have printed thereon "Tax for experiment farm—yes"; "Tax for experiment farm—no". The result of such election shall be ascertained by the board of deputy supervisors of elections and the result thereof certified to the county auditor.

Sec. 1165-5. If a majority of the electors voting on such proposition in the county, are in favor of establishing such experiment farm, then the commissioners of the county shall levy a tax on all the taxable property in such county as listed for taxation on the county duplicate, which levy shall not exceed one-fifth of one mill on the dollar of the taxable property of the county in any one year, nor shall the aggregate of all levies for such purpose exceed two mills on the dollar.

Sec. 1165-6. To anticipate the collection of the tax authorized by this act and the use of the money to be raised thereby, the commissioners are hereby authorized and required to issue the notes or bonds of their county, such notes or bonds to bear interest at a rate not to exceed six per cent. per annum, and not to run to exceed ten years, and not to be sold for less than their par value, and the proceeds of the sale thereof shall be deposited in the county treasury, to be applied by the commissioners to the purchase and equipment of an experiment farm, containing eighty acres or more, as hereinafter provided for.

Sec. 1165-7. When the funds provided for in this act are deposited in the county treasury, the commissioners shall notify the board of control of the Ohio Agricultural Experiment Station of their action, on receipt of which notice it shall be the duty of said board of control to visit the county and assist in the selection of a farm to be used for the purpose specified in this act, provided that no farm shall be purchased except with the approval of the majority of the members of said board of control and also of a majority of the board of county commissioners of the county.

Sec. 1165-8. The equipment of an experiment farm shall consist of such buildings, drains, fences, implements, live stock, stock feed and teams as shall be deemed necessary by the board of control of the experiment station for the successful work of such farm, and the initial equipment shall be provided by the county in which the farm is established, together with a sufficient fund to pay the wages of the laborers required to conduct the work of such farm during the first season. The county commissioners shall appropriate for the payment of the wages of laborers employed in the management of such farms as may be established under this act, and for the purchase of supplies and materials necessary to the proper conduct of such farms such sums not exceeding two thousand dollars annually for any farm, as may be agreed upon between said commissioners and the board of control of the experiment station.

Sec. 1163-9. The management of all experiment farms established under authority of this act shall be vested in the director of the Ohio Agricultural Experiment Station, who shall appoint all employees and plan and execute the work to be carried on, in such manner as in his judgment will most effectively serve the agricultural interests of the county in which such farm may be located, the director and all employees being governed by the general rules and regulations of the board of control of said Experiment Station.

Sec. 1165-10. Before entering upon any line of investigation or demonstration upon any of the experiment farms established under this act, the director of the experiment station shall submit a written plan of such contemplated work to an advisory board, consisting of the county agricultural society of the county in which such experiment farm may be located, or if there be no county agricultural society, then of the board of county commissioners of such county, and if such plan is not approved by such advisory board, then the work shall not be undertaken.

Sec. 1165-11. The county commissioners of any county may assign to the board of control of the Experiment Station such portion of any farm now owned by the county as may be mutually agreed upon between the commissioners and the board of control, the land thus assigned to be occupied and used by the experiment station for the purpose specified in this act and under the management of the director of the station.

Sec. 1165-12. The produce of each of such experiment farms as may be established under this act, over and above that required for the support of the teams and live stock kept on the farm, shall be sold and the proceeds applied to the payment of the labor and to the purchase of the supplies and materials required for the proper management of the farm as contemplated by this act, and for the maintenance of its equipment. Any surplus beyond these requirements shall be covered into the county treasury and placed to the credit of the general fund of the county, except in case of the use of farms already belonging to the county, in which case the proceeds shall be placed to the credit of such fund as the county commissioners may designate.

Sec. 1165-13. In case the experiment station shall cease to use for the purposes herein specified any farm established under this act, such farm and its equipment shall be sold at public auction to the highest bidder after notice of such proposed sale shall have been published for four consecutive weeks in two newspapers of opposite politics, once a week, published in and having the largest circulation in the county within which the farm is located, and the proceeds of such sale shall be covered into the county treasury, the sums thus covered to be placed to the credit of the school funds of the county.

GRANVILLE W. MOONEY,

Speaker of the House of Representatives.

FRANCIS W. TREADWAY,

President of the Senate.

Passed April 13, 1910.

Approved April 23, 1910.

JUDSON HARMON, Governor.

ANNUAL REPORT

This law, it will be observed, is wholly optional in character merely providing a way by which the counties may inaugurate local demonstrations of the results which are being worked out at the central Station, and by which local problems and conditions may be more efficiently and thoroughly studied by the Station.

It is proper to state that this measure did not originate with the Experiment Station, but with a sub-committee of the Finance Committee of the House of Representatives, of which Mr. Wilber was a member, on their visit to the Station to inquire into its work and needs.

PERSONNEL

The term of office of Dr. W. I. Chamberlain having expired, Hon. Joseph D. Guthery, of Marion County, was appointed to succeed him.

At the annual meeting of the Board, held in March, the following organization was affected: President, John Courtright; Secretary, Henry L. Goll; Treasurer, D. L. Sampson.

Respectfully submitted,

HENRY L. GOLL,

Secretary of the Board of Control.

REPORT OF THE BURSAR.

MR. JOHN COURTRIGHT, *President of the Board of Control:*

DEAR SIR: I respectfully submit herewith the financial report of the Station for the fiscal year ending June 30, 1910.

In statements A, B, C, D and E, respectively, will be found a record of receipts and expenditures from the various funds; statements A and B being statements of account with the appropriations received from the U. S. Treasury and a copy of the report made to the Governor of the State, the U. S. Secretary of Agriculture, and the Secretary of the U. S. Treasury: statment C being a statement of account with the State Treasury, and statement D showing the receipts from farm produce and other sources and the expenditures from that fund.

The four statements, A, B, C, and D. are combined in statement E, which shows the total income and expenditures for the fiscal year.

STATEMENT A

Hatch Fund

THE OHIO AGRICULTURAL EXPERIMENT STATION IN ACCOUNT WITH THE
UNITED STATES APPROPRIATION UNDER THE HATCH ACT
FOR 1909-1910.

Dr.

To receipts from the Treasurer of the United States, as
per appropriation for the fiscal year ending June 30,
1910, as per act of Congress approved March 2, 1887.....\$ 15,000.00

Cr.

By expenditures for:—

Salaries	\$13,857.50
Publications	260.00
Postage and stationery.....	100.17
Traveling expenses.....	17.33
Contingent expenses.....	15.00
Buildings and repairs.....	750.00
Total	\$ 15,000.00

OHIO EXPERIMENT STATION

STATEMENT B

Adams Fund

THE OHIO AGRICULTURAL EXPERIMENT STATION IN ACCOUNT WITH THE
UNITED STATES APPROPRIATION UNDER THE ADAMS ACT
FOR 1909-1910

Dr.

To receipts from the Treasurer of the United States, as
per appropriation for the fiscal year ending June 30,
1910, as per act of Congress, approved March 16, 1906..... \$ 13,000.00

Cr.

By expenditures for:—

Salaries	\$9,765.00
Labor	367.32
Chemical supplies	717.50
Seeds, plants and sundry supplies	15.29
Library	66.43
Scientific apparatus.....	1,144.32
Live stock	193.00
Traveling expenses	81.78
Building and repairs	649.36
Total.....	\$ 13,000.00

We, the undersigned, duly appointed Auditors of the Corporation, do hereby certify that we have examined the books and accounts of the Ohio Agricultural Experiment Station for the fiscal year ended June 30, 1910, that we have found the same well kept and classified as above; that the receipts for the year from the Treasurer of the United States are shown to have been \$15,000.00 under the act of Congress of March 2, 1887, and \$13,000.00 under the act of Congress of March 16, 1906, and the corresponding disbursements \$15,000.00 and \$13,000.00; for all of which proper vouchers are on file and have been examined and found correct.

And we further certify that the expenditures have been solely for the purposes set forth in the acts of Congress approved March 2, 1887, and March 16, 1906, and in accordance with the terms of said acts, respectively.

Signed:

JOSEPH D. GUTHERY,

D. L. SAMPSON,

Auditors.

STATEMENT C

State Appropriations

THE OHIO AGRICULTURAL EXPERIMENT STATION IN ACCOUNT WITH THE
STATE TREASURY

Date of appro- priation	Appropriation for:—	Total amount to Station's credit	Total amount expended	Balance in treasury June 30, 1910
1910	Administration	\$ 26,300.00	\$ 5,084.81	\$ 21,215.19
	Furniture and Carpets	500.00		500.00
	Agronomy	16,475.00	3,194.34	13,280.66
	Animal Husbandry	15,000.00	3,970.52	11,029.48
	Botany	10,900.00	1,711.24	9,188.76
	Cooperative Experiments	20,470.00	6,162.55	14,307.45
	Entomology.....	5,000.00	765.14	4,234.86
	Forestry	10,000.00	2,339.42	7,660.58
	Soils.....	10,500.00	2,963.16	7,536.84
	Chemistry	3,700.00		3,700.00
	Horticulture	10,950.00	2,648.68	8,301.32
	Nutrition	4,000.00	61.15	3,938.85
	Dairy Husbandry.....	8,000.00		8,000.00
	Completing Nutrition Building	17,000.00		17,000.00
	Purchase of land	4,000.00		4,000.00
	States share of assessment } for road construction }	500.00		500.00
	Extension of Power House.....	3,000.00		3,000.00
	Totals for 1910.....	\$166,295.00	\$ 28,901.01	\$137,393.99
1909	Administration	\$ 15,203.79	\$ 15,203.79	
	Agronomy	8,302.01	8,302.01	
	Animal Husbandry	12,249.06	12,249.06	
	Botany	4,066.39	4,066.39	
	Cooperative Experiments	11,379.94	11,379.94	
	Entomology.....	5,551.24	5,551.24	
	Forestry	6,847.98	6,847.98	
	Soils	4,115.94	4,115.94	
	Furniture and Carpets.....	857.80	426.53	431.27
	Chemistry	3,180.62	2,454.73	725.89
	Horticulture	7,673.72	7,673.72	
	Nutrition	7,925.60	3,189.48	4,736.12
	Totals for 1909 and 1910 ...	\$253,649.09	\$110,361.82	\$143,287.27

OHIO EXPERIMENT STATION

STATEMENT D

Produce Fund

THE OHIO AGRICULTURAL EXPERIMENT STATION IN ACCOUNT WITH THE
PRODUCE FUND

*Dr.**To Receipts*

From Department of Administration	\$ 800.50	
“ “ “ Agronomy	1,369.61	
“ “ “ Animal Husbandry	7,199.90	
“ “ “ Botany	.70	
“ “ “ Cooperative Experiments	2,246.78	
“ “ “ Entomology	37.60	
“ “ “ Forestry	177.26	
“ “ “ Horticulture	3,741.42	
“ “ “ Nutrition	365.77	
“ “ “ Soils	2,019.71	
Total receipts for the year	\$ 17,959.25	
To balance brought forward July 1, 1909	5,973.26	
Total	\$ 23,932.51	

*Cr.**By Expenditures*

For Salaries	\$ 2,533.34	
“ Labor	2,262.83	
“ Postage and stationery	285.67	
“ Freight and express	451.35	
“ Heat, light, water and power	323.02	
“ Chemical supplies	225.03	
“ Seeds, plants and sundry supplies	1,412.40	
“ Fertilizers	32.50	
“ Feeding stuffs	3,592.69	
“ Library	56.35	
“ Tools, implements and machinery	1,674.82	
“ Scientific apparatus	15.25	
“ Live stock	3,237.16	
“ Traveling expenses	1,192.61	
“ Contingent expenses	306.83	
“ Buildings and repairs	4,121.08	
Total expenditures for the year	\$ 21,722.93	
By balance carried forward	2,209.58	
Total	\$ 23,932.51	

STATEMENT E

Totals

TOTAL RECEIPTS AND EXPENDITURES OF THE OHIO AGRICULTURAL EXPERIMENT STATION FOR THE YEAR ENDING JUNE 30, 1910.

*Dr.**Total Receipts*

From United States Appropriations.....	\$ 28,000.00	
“ State appropriations.....	166,295.00	
“ Produce Fund	17,959.25	
Total receipts for the year	\$ 212,254.25	
To balance brought forward July 1, 1909.....	93,327.35	
Totals	\$ 305,581.60	

*Cr.**By Expenditures*

For Salaries.....	\$ 55,443.89	
“ Labor.....	31,882.12	
“ Publications	7,778.80	
“ Postage and stationery.....	1,722.65	
“ Freight and express.....	2,774.65	
“ Heat, light, water and power	2,659.98	
“ Chemical supplies.....	2,636.89	
“ Seeds, plants and sundry supplies	8,097.38	
“ Fertilizers.....	1,020.69	
“ Feeding stuffs.....	6,121.65	
“ Library.....	855.13	
“ Tools, implements and machinery	6,592.46	
“ Furniture and fixtures	426.53	
“ Scientific apparatus	3,206.70	
“ Live stock	8,085.67	
“ Traveling expenses	9,289.69	
“ Contingent expenses.....	613.77	
“ Buildings and repairs.....	10,876.10	
Total expenditures for the year	\$ 160,084.75	
By balance carried forward.....	145,496.85	
Total	\$ 305,581.60	

Respectfully submitted,

W. H. KRAMER, *Bursar.*

REPORT OF THE DIRECTOR

HON. JOHN COURTRIGHT, *President of the Board of Control:*

SIR: I have the honor of submitting the following report of the work of this Station for the year ended June 30, 1910.

THE STATION'S WORK

In general the work of the Station has followed closely along the lines described somewhat in detail in my last report.

The principal features of the work of the year have been as follows:

AGRONOMY

Varietal and cultural work. The work of the Agronomy department is being continued along lines similar to those of last year with the following field crops: Alfalfa, clover, corn, cowpeas, special forage crops, meadow grasses, oats, soybeans and wheat. This work includes the testing of old and new varieties; the testing of methods, rates and times of seeding, and the improvement of existing varieties by plant selection and breeding.

In the testing of varieties some 25 different sources of alfalfa seed are being studied; 35 varieties of corn, 25 of which are pedigreed strains developed in our ear-row breeding; 4 varieties of field peas; 10 species of grasses; 60 varieties of oats in tenth-acre plots and 74 in hundredth-acre plots; 51 varieties of soybeans, 34 of which are superior pure line selections in hundredth-acres.

In the study of methods of seeding, work is being carried on with alfalfa, clover, corn and oats. In rate of seeding, with alfalfa, corn, oats, soybeans and wheat. On the best time of seeding, with alfalfa, corn oats and wheat. On the relation of size and weight of seed to yield, with oats and wheat.

Crop improvement work. In this work 130 strains of alfalfa are being propagated from seed from as many different plants; 245 strains of red clover; 100 strains of corn; 569 strains of oats; 125 strains of soybeans and 1560 strains of wheat.

The work in crop improvement is oldest with corn. Pedigreed strains have been developed which are thus far yielding 5 to 14 bushels per acre more than the original varieties from which they have been selected and bred; pedigreed strains of oats and wheat are yielding 3 to 6 bushels in advance of original stock, and of soybeans, $2\frac{1}{2}$ to 6 bushels.

In studies in corn of the relation of prominent ear characters to yield, evidence is accumulating showing that the use of seed ears of less than normal length for a given variety or locality will reduce the yield, and that the continuous use of ears having an inch to an inch and a half of bare cob at the tip decreases the yield of shelled corn per acre. In other words this character seems to be hereditary; that ears comparatively smooth in indentation—merely crease dented, are somewhat superior in yield to very rough-dented ears; that when the conditions of growth are equal, and the ears compared are equal in maturity, weight of ear is a partial guide in the selection of productive seed, and that shape of ear as regards cylindricity is a matter of less importance than the above mentioned characters.

New work. Milling and baking tests of the Station's different varieties and selections of wheat are now in progress. These tests are showing interesting variations and will prove of value to the State when they have been confirmed by repeated tests made during several different seasons.

Cooperative work. Cooperative work is being carried on by farmers in several counties of the State in the testing of corn, soy-beans, oats and wheat. It is proposed to extend this work very largely.

A study of two systems of farming, one with, the other without livestock, has been inaugurated.

ANIMAL HUSBANDRY AND DAIRYING

The lines of work reported upon last year are being continued. A study of the various proportions of grain and roughage in the ration for beef production has been begun, and in the use of various roughages for mutton production.

New work. Studies in wool production have been begun. This work will be prosecuted from the standpoints of both the wool producer and the textile worker.

Experiments in pasture improvement have been undertaken at the Central Station and the Southeastern Test-farm, which it is hoped to extend to other sections of the State.

Work with poultry has been begun on a limited scale at the Southeastern Test-farm. It is planned to extend this work as fast as the Station's resources will permit.

Buildings. During the past year a much needed swine barn has been erected, and the barn occupied by the breeding and dairy cattle has been so altered and repaired as to make it more sanitary and convenient. Funds are now available for erecting a storage and sheep barn at the Southeastern Test-farm.

The last General Assembly having made provision for a Department of Dairying, the Department of Animal Husbandry will hereafter include the production of meat and wool and the feeding of horses.

When the Department of Dairying is organized the management of the dairy cattle will be transferred to this department.

BOTANY

Three separate lines of work are included in the Department of Botany, namely: I—Examination of seeds for purity and germinability, and identification of weeds, with suggestions for their control. II—the investigation of plant diseases and of methods for their control, and III—Plant breeding work with tobacco.

Seeds and weeds. About 425 samples of seeds have been tested during the year for purity, and germination tests have been made of about 200 samples. An effort is made to identify such seed impurities as the dodders and plantains in clover and alfalfa and to detect the adulteration of seeds with inferior varieties. It is hoped that this work may be placed by law with the State Department of Agriculture under a general provision for seed inspection and control. Numerous collections of weed seeds made by pupils in country schools have been identified.

Weed spraying. In 1909 some preliminary work was done in this method of weed control with encouraging results, and the last General Assembly has increased the appropriations to this department of the Station by \$1000, to be used in further investigations along this line. Preparations are being made to give this method a thorough test during this season.

Plant diseases. This phase of the work of the department includes several more or less separate lines of work. During the past two years the diseases of the cereals have received special attention. The bacterial blight of oats, which caused such a loss in this crop of 1907 and 1908, is reported upon in Bulletin 210. Some diseases in corn and greenhouse crops, truck crops and fruits, are now under investigation, both through laboratory investigations at the Station and by field experiments in cooperation with fruit growers and truck gardeners.

Diseases of forest and shade trees. Special provision was made for this work in the appropriations for the current year, and it is being undertaken in cooperation with the Forestry Department of the Station.

Plant breeding. For some years the Department of Botany has carried on work in the hybridizing of wheat and oats. A few hybrids obtained in this way are being tested out at the Station and on the outlying test farms. The principal part of the breeding work of this department is being conducted on tobacco, in response to the request of the Tobacco Growers' Union, made at the time the Germantown Test-farm was established. Several hundred tobacco

hybrids are now under investigation, some of which are quite promising. The Bureau of Plant Industry, of the U. S. Department of Agriculture, has assigned a special agent, to work during 1910 in cooperation with this Station in tobacco investigations.

CHEMISTRY

The Chemical Department continues to be chiefly occupied in studies of the relationship between the chemical composition of soils and crops. Eighty-five samples of soils, collected in different parts of the state, are being subjected to complete chemical analysis, both the total and acid soluble constituents being determined. In connection with this work crops grown under different treatments are being analyzed. This work is bringing out the differences in composition between the soils of the limestone and sandstone areas of the State, and is showing that the lack or abundance of phosphorus in the soil is reflected in the crops produced.

COOPERATION

Field experiments. The number of cooperative field experiments being conducted this year is somewhat smaller than in years past, and effort is being made to restrict these experiments to such as may receive personal attention in the field and may also be part of some specific investigation which is being conducted either by this department or some other department of the Station. Material has been supplied for such experiments with corn, alfalfa, grasses, soybeans, potatoes and other crops, and a few fertilizer experiments have been started.

County fair exhibits. The legislature has made provision for putting a third exhibit on the road during the fair season, and through the courtesy of the Fair Managers Association, good shipping routes, reaching largely into counties in which the exhibit has not previously been shown, have been worked out for each of the three exhibits. The State Railroad Commission has kindly arranged with the railroads for a uniform rating for the shipment of the exhibit. In order to assist in advertising it, a descriptive, illustrated circular has been issued, which will be supplied to fair associations as needed.

Farm management investigations. The advancing price of land and labor make it increasingly important that close attention be given to the business methods of the farm. The Station is making a study of the systems of rotation and general management that are being practiced throughout the state, including the several sub-divisions of farm work, such as dairying, poultry keeping, etc. About 80 dairymen and 100 poultrymen are now cooperating with the Station in this work. On a smaller number of farms all the

enterprises that enter into their operation are being studied in cooperation with the office of Farm Management Investigations of the Bureau of Plant Industry, U. S. Department of Agriculture.

Statistics of crop production. The necessary foundation on which to build a better system of management is the knowledge of what is now being done. To obtain this knowledge statistics of crop production in the state are collected annually by the township assessors. Thus far these statistics have been buried in the annual reports of the Departments of State and Agriculture. The Station has arranged the statistics of some of the principal crops of the State for 1908 and 1909 in such a manner as to show the centers of chief production in the State, and has arranged with the U. S. Bureau of Census for a tabulation by townships of Ohio's corn crop, in order that comparison may be made with the statistics collected by the township assessors.

FORESTRY

Forest work at the Station. At Wooster the Forestry Department has a nursery containing about 225,000 seedling trees. About 125,000 catalpa, 50,000 locust, and 20,000 white ash seedlings will be propagated this spring. Aside from this about 15 pounds of white pine seed has been sown and about 100,000 seedlings may be expected, providing the season is favorable. There are about 10,000 ornamental trees in the nursery rows which will be tested under various conditions in different parts of the State.

Three native woodlots at the Station farm are being reconstructed and considerable planting and improvement work will be done this spring and next. Different kinds of trees will be used and different distances of planting and different mixtures of trees will be tested. Every forest tree which gives promise of some value and seems adapted to the site will be tried out. In one of the woodlots both practical and aesthetic forestry will be practiced. That is, useful forest trees will be planted and yet combined and grouped in such a manner as to produce both practical and aesthetic results.

Several woodlots are also being reafforested at the Southeastern Test-farm, but a serious loss has been suffered here through fire started from the railroad.

Cooperative forestry. From the nature of the work the greater part of its forestry operations must be carried on away from the Station. Cooperative work consists of two kinds: first, with farmers, and second, with state and municipal institutions. The latter, in most cases, is more satisfactory, because it insures greater permanency than the former. Cooperative work with the farmers and land owners will be continued, but efforts will be directed towards the

ANNUAL REPORT

care of the native woodlots in preference to the planting of groves and plantations. So much interest has been aroused in the latter case, especially where locust and catalpa were used, that it seems justifiable to restrict the giving out of these species to cases where good opportunities present themselves for demonstration or experimentation, or to localities where little interest has been manifested in the past. It seems advisable to offer every inducement possible in the way of furnishing different kinds of trees for woodlot improvement. The increase of interest in woodlot management is apparent. Out of 208 applicants for help in forestry work, 73 were for aid in managing woodlots, being double the number for the previous year. Work among the land owners in southern Ohio will be pushed as far as time and funds permit. Some of the iron and coal companies have applied for help in managing their lands. A map of the land of the Carbondale Coal Company, in Athens county, was partially prepared last summer, and will be completed this year. Plans for operation will accompany the map.

The experimental planting of pine and locust for the purpose of reclaiming eroded waste lands is of the utmost importance, and work will be conducted along this line. The locust is especially well adapted for this purpose, on a small scale, because of its value for post timbers, its adaptability to the conditions, and its propensity to aid in the establishment of blue-grass sod.

Forestry at public institutions. The Experiment Station is now conducting forestry work on the cooperative plan at seven state and municipal institutions, and at one private institution. These are: The State Reformatory, Mansfield; The Tuberculosis Hospital, Mt. Vernon; The Boys' Industrial School, Lancaster; Miami University, Oxford; The Hospital for the Criminal Insane, Lima; The University of Cincinnati, Cincinnati; Oberlin Water Works Farm, Oberlin; Kenyon College, Gambier. Work will be carried on with each institution this year. The lands of these institutions represent almost every soil and topographical condition in Ohio, and practically every one offers excellent opportunities for different phases of forestry work. Opportunity is offered for the management of second growth forest and the reconstruction of old woodlots and for plantation plantings. One of the most important experiments now going on is the planting on the Oberlin Water Works Farm of 100 acres, to protect the intake of the reservoir. A considerable number of white pines were planted on this farm this spring and the work will be continued in the future.

Forest survey. The department has employed six men for the summer to assist in preparing maps and working plans for the various state institutions where work is being carried on. As far as time permits, the work will be extended to the more promising tracts of the companies and individuals where work can be done.

Studies of commercial trees will also be conducted. The study of the chestnut will be completed and the results published.

HORTICULTURE AND ENTOMOLOGY

Revival of apple culture in Ohio. For several seasons these departments of the Station have been working in cooperation with orchardists in various sections of the State, with the result that it has been convincingly demonstrated that it is possible to bring back many an abandoned orchard into very profitable production, and it is no longer a question that many a hill farm in southeastern Ohio, which is now affording its owner but a meager subsistence, might be made to yield an income rivalling those obtained from the more level lands of the State, if planted in apples and properly cared for.

NUTRITION

The work of this department, which is being conducted under the Adams Fund, has included investigations on (1) the nutritive values of the various compounds of phosphorus in foods; (2) the separation of the various groups of phosphorus compounds in food-stuffs, and (3) the effects of conditions of growth on the mineral nutrients in blue-grass.

Plans have been completed for the construction of a building for slaughter, refrigeration and metabolism experiments, appropriations for which purpose, amounting to \$22,000, have been made by the last two General Assemblies. This building is to be of brick, 40x60 feet on the ground, with two stories and a basement. The first floor is devoted to slaughter and refrigeration work, the coolers occupying 18x38 feet and providing for temperatures from zero to 40 degrees Fahrenheit. The second floor will contain an animal experiment room 23x39 feet in size and four smaller accessory rooms for various experimental operations.

The character of the work of this department is illustrated by the three bulletins issued during the year, Numbers 207, 213 and 215. In Bulletin 207 it is shown that the specific or characteristic effects of foods are influenced in important ways by the ratio of the inorganic acids to the inorganic bases which they contain. A ration which contains a fair proportion of fruits, vegetables, milk or roughage, is likely to furnish a sufficient amount of the bases (sodium, potassium and calcium) in relation to the acids (sulphur, phosphorus and chlorine); but a ration made up of little else than the cereal foods, eggs and meat, is liable to be deficient in the base and to contain an excess of the acids.

In Bulletin 213, which was published jointly with the Experiment Station of the University of Missouri, a comparison of a considerable number of balanced rations shows that the muscular growth produced was generally in accord with the content of the foods in organic phosphorus compounds. As a food for growing animals it is shown that corn is deficient in protein, calcium and phosphorus, also in basic minerals as compared with acid minerals, and further, is characterized by an excess of magnesium in relation to calcium. The effects of these conditions, as exhibited by the growth of pigs, are a retarded development of proteid and bony tissues and an over-development of fatty tissue. Such animals reach their limit of growth prematurely and their breeding capacity is impaired by the lessened circulation of blood in the reproductive organs, due to the pressure of an excess of internal fat.

In Bulletin 215 new methods are published to supplant very imperfect ones for distinguishing between organic phosphorus, which contributes to the growth of all the tissues of the body, and inorganic phosphorus, which contributes only to the growth of bones.

These studies of the nutritive values of phosphorus compounds are showing that glycerophosphates are more useful than the other organic and inorganic compounds found in foods. The content of farm foods of phosphorus in this condition is very small, and it seems probable that the results of these experiments will show that under certain conditions of practice it will pay to add glycerophosphates to the food just as we use common salt.

It will be seen from the foregoing summary that the work of this department is being directed toward some of the fundamental problems in the nutrition, both of the lower animals and of man.

SOIL INVESTIGATIONS

These investigations have been continued without interruption at the main station and at the three test-farms, and work has been begun on the Findlay and Boardman test-fields. The work at the main station includes field experiments, pot-cultural studies in the greenhouse and analyses of soils and crops in the chemical laboratory. In these pot-cultural and chemical investigations a large number of soils from the different soil formations of the State are being studied, and while useful information is being obtained through these methods they do not and probably never can take the place of the field experiment.

In the chemical laboratory improved methods of investigation are being developed which are making it possible to determine in a general way the condition of a particular soil, but the more accurate

knowledge which is essential to the most economical management of the land is only to be obtained in the field itself, and only through investigations comprehensive in plan and continued through many years.

The work which has thus far been accomplished in this direction gives very great encouragement to the expectation that it will ultimately be possible to outline a system of treatment for a particular soil which will give the highest results in economy of production, but to accomplish this end it will be necessary to know the geological history of the soil, its chemical and physical constitution and the treatment to which it has been subjected for a considerable period of years. Neither of these factors can be omitted from the computation, but if either is more important than the others it is probably the first and the last.

For this reason it is useless to send a sample of soil to the Experiment Station for examination unless the sample be accompanied by information respecting its location and previous treatment, and before the Experiment Station can have that thorough knowledge of the soil formations of the State which is essential to accuracy in advice it must have more of these formations under field investigation.

COUNTY EXPERIMENT FARMS

In another part of this report is given the text of the law enacted last winter which authorizes the establishment of county experiment farms. Should there be any considerable number of such farms established under this law it will be possible to materially extend our knowledge of the soils of the State, for the first work undertaken on such a farm should be the study of its soil. To the end that this study may be of the greatest value to the county as a whole the farm should be located upon a soil typical of as large an area of the the county as possible, except in some cases where in adjoining counties it may be better to locate the experiment farms on different soil types, even though one of these types may represent a smaller area than the other.

WHAT THE COUNTY EXPERIMENT FARMS MAY ACCOMPLISH

The Experiment Station was located in Wayne county in 1892, on a soil representing the average soils of the county in geological origin and in present condition, though somewhat below the average in natural fertility. The Station at once instituted a series of experiments on this soil, which were so planned as to bring out the comparative effect of different kinds and quantities of fertilizing materials and manures, a part of the land being left continuously without treatment for comparison. The outcome of this work is, that in a

rotation of corn, oats and wheat, one year each, followed by clover and timothy two years, the crops produced have had an average annual value for the last five years of \$12.66 per acre, computing corn at half a dollar per bushel, oats at one-third of a dollar, wheat at one dollar and hay at eight dollars per ton, on land that has had no fertilizing or manuring. The use on the corn, oats and wheat of a complete chemical fertilizer, costing \$23.50 for each rotation, or \$4.70 annually, has increased the annual value of the produce to \$20 per acre. When the rotation has been reduced to four years, by omitting the timothy crop, and ten tons of barnyard manure, reinforced with phosphate rock and followed by a ton of lime per acre has been applied to the corn crop, and 400 pounds per acre of complete commercial fertilizer has been applied to the wheat, the cost of treatment, in addition to the manuring, amounting to \$14.00 for each 4-year rotation, or \$3.50 annually, the average annual value of the produce has amounted to more than \$30 per acre on forty acres of land.

This last result has been accomplished by applying to large-field culture the lessons taught by the small-plot experiments, and the outcome is a larger yield, produced at a less cost than any that has been secured in the plot work.

This study of the maintenance and increase of the produce of the land should be the leading work of the county experiment farms, for the Station's work on its several test farms has shown that the results attained on the Wooster soil cannot be accepted as an assurance that similar results will follow similar methods on other soils. For example, the same application of chemical fertilizers which has given increase to the value of \$50 at Wooster has increased the produce by only \$28 at the Strongsville Test-farm, while at the Germantown Test-farm the rate of increase, during the first six years of the work, has been greater than that at Wooster during the corresponding period.

Next to the study of the soil will come investigations on the adaptability of different varieties of grains and forage crops to the different sections of the State, and on different methods of culture. In some sections, also, studies will be made of certain crops which are not adapted to the soils of the State in general; for example, of the sugarbeet in northwestern Ohio.

As these county farms will be branches of the main station, their work will be coordinated with that of the Station, thus systematizing the work throughout the State and bringing to each county the direct assistance of the specialists employed at the main station and of the results being attained at all the other county stations.

Of course the chemical, physical and bacteriological laboratories, with their costly equipment, will remain at the main station, and such questions as require their facilities for solution will be carried to them.

PUBLICATIONS

The following publications have been issued during the year:

Bulletin 206, pp. 1-21. The maintenance of fertility: Field experiments with fertilizers and manures on tobacco, corn, wheat and clover in the Miami Valley. By C. E. Thorne.

Bulletin 207, pp. 23-52. The balance between inorganic acids and bases in animal nutrition. By E. B. Forbes.

*Bulletin 208, pp. 53-70. Protection of fruit trees from rodents. By F. H. Ballou.

*Bulletin 209, pp. 71-89. Rations for fattening swine. By B. E. Carmichael.

*Bulletin 210, pp. 91-167. The blade-blight of oats. By Thos. F. Manns.

*Bulletin 211, pp. 169-212. Third annual report on forest conditions in Ohio. By C. E. Thorne, W. J. Green and Edmund Secrest.

*Bulletin 212, pp. 213-236. Corn judging: Studies of prominent ear-characters in their relation to yield. By C. G. Williams and F. A. Welton.

*Bulletin 213, pp. 237-305. Specific effects of rations on the development of swine. By E. B. Forbes.

*Bulletin 214, pp. 307-456. A brief handbook of the diseases of cultivated plants. (A revision of Bulletin 121). By A. D. Selby.

*Bulletin 215, pp. 457-489. Methods for the quantitative estimation of inorganic phosphorus in vegetable and animal substances. By E. B. Forbes, A. Lehmann, R. C. Collison and A. C. Whittier.

*Bulletin 216, pp. 491-526. Spraying machinery. By W. H. Goodwin.

*Bulletin 217, pp. 527-559. Apple culture in Ohio. By F. H. Ballou.

*Bulletin 218, pp. 561-603. I. The Status of the potato industry in Ohio. By F. H. Ballou. II. Seasonal notes on potatoes. By J. H. Gourley.

*Bulletin 219, pp. 605-639. The relative durability of post timbers. By W. J. Green and J. J. Crumley.

*Bulletin 220, pp. 641-673. Annual report, meteorological summary, press bulletins and index.

*Circular 96, October 1, 1909, 36 pp. Essentials of successful field experimentation. By C. E. Thorne.

*Circular 97, January 20, 1910, 8 pp. The work of the department of cooperative experiments. By L. H. Goddard.

*Circular 98, February 1, 1910, 18 pp. Minor items of farm equipment. By L. H. Goddard and L. W. Ellis.

*Circular 99, March 1, 1910, 8 pp. Cooperative dairy work. By L. H. Goddard and M. O. Bugby.

*Circular 100, April 7, 1910, 15 pp. The centers of agricultural production in Ohio. By L. H. Goddard.

*Circular 101, May 12, 1910, 15 pp. Illustrative exhibits at state and county fairs. By L. H. Goddard and W. A. Lloyd.

*Circular 102, May 20, 1910, 7 pp. Spraying to kill weeds. Some useful methods. By A. D. Selby.

The publications marked (*) have been sent to the entire mailing list of the Station. The other numbers have been published in small editions and sent only to special lists of names, but a few copies are still available for distribution to those who may request them.

Eleven press bulletins have been issued during the year, Nos. 304 to 314 inclusive. These are republished with the present report.

PERSONNEL

Messrs. L. T. Bowser and L. L. Scott, assistants in the departments of chemistry and entomology, have resigned their positions to accept other situations. Mr. Thos. F. Manns has been transferred to the department of Soils as Soil Bacteriologist, and the following new appointments have been made: Albert G. Woods and E. G. Arzberger, B. S., Assistant Botanists; R. D. Whitmarsh, B. S., Assistant Entomologist; and George Boltz, B. S., Assistant Chemist.

Respectfully submitted,

CHAS. E. THORNE, Director.

APPENDIX

Bulletins

OF THE

Ohio Agricultural Experiment Station.

1909-1910

CONTENTS.

	BUL.	PAGE
Maintenance of fertility.....	206	1
Balance between inorganic acids and bases in animal nutrition	207	23
Protection of fruit trees from rodents	208	53
Rations for fattening swine.....	209	71
The blade blight of oats.....	210	91
Third annual report of forest conditions in Ohio.....	211	169
Corn judging	212	213
Specific effects of rations on the development of swine	213	237
A brief hand book of the diseases of cultivated plants in Ohio.....	214	307
Methods of quantitative estimation of inorganic phosphorus in vegetable and animal substances.....	215	459
Spraying machinery.....	216	491
Apple culture in Ohio	217	527
Status of the potato growing industry in Ohio.....	218	561
Relative durability of post timbers.....	219	605
Meteorological summary; press bulletins; index	220	641

BULLETIN

OF THE

Ohio Agricultural Experiment Station

NUMBER 206.

AUGUST, 1909

EXPERIMENTS WITH FERTILIZERS AND MANURE ON TOBACCO, CORN, WHEAT AND CLOVER IN THE MIAMI VALLEY

These experiments were begun in 1903 on tobacco, grown both continuously and in rotation with wheat and clover, and in 1904 and 1905 on corn and wheat, grown in a rotation of corn, wheat and clover. A description of the soil and the plan of the experiments with tobacco are given in Bulletin 161 of this Station, and a continuation of the work with tobacco up to 1905 is reported in Bulletin 172. The rotation of corn, wheat and clover is in part reported in Bulletin 182, and the statistics of all the crops up to 1906 are given in Bulletin 184.

I: FERTILIZERS AND MANURE ON TOBACCO GROWN IN ROTATION

The plan of fertilizing in the rotation of tobacco, wheat and clover is given in Table I and Diagrams I and II; the statistics of yield for the years 1907 and 1908 are given in Table II, and a general summary of the results for the entire period is given in Table III, in which the yields of tobacco are grouped in two 3-year periods, thus showing the cumulative effect of the fertilizers during the second period.

DIAGRAM I: ARRANGEMENT OF PLOTS IN TOBACCO-WHEAT-CLOVER ROTATION

Section A

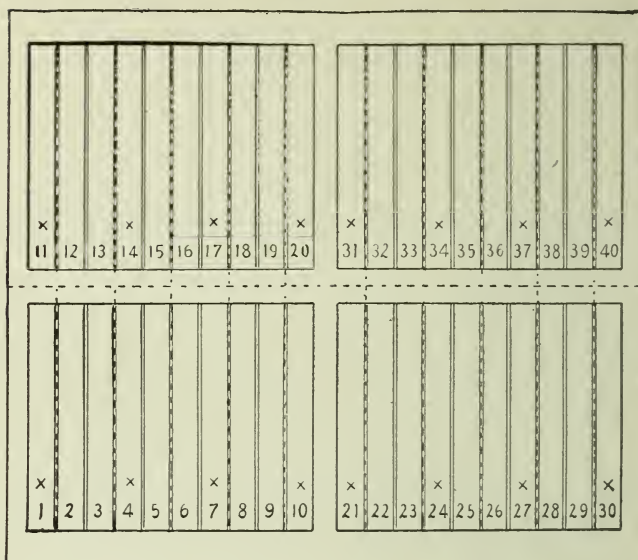


TABLE I: PLAN OF FERTILIZING TOBACCO GROWN IN ROTATION.

Plot No.	Fertilizing materials per acre (All applied to the tobacco crop)	Fertilizing elements per acre		
		Phos- phorus	Potas- sium	Nitro- gen
		Lbs.	Lbs.	Lb
1	None	..	..	..
2	Acid phosphate, 480 lbs.	30	..	..
3	Acid phosphate, 480 lbs.; muriate potash, 180 lbs.	30	75	..
4	None	..	..	..
5	Muriate potash, 180 lbs.; nitrate soda, 240 lbs.	..	75	38
6	Acid phosphate, 480 lbs.; nitrate soda, 240 lbs.	30	..	38
7	None	..	..	..
8	Acid phos., 480 lbs.; mur. potash, 180 lbs.; nit. soda, 240 lbs.	30	75	38
9	Acid phos., 480 lbs.; mur. potash, 300 lbs.; nit. soda, 240 lbs.	30	125	38
10	None	..	..	..
11	None	..	..	..
12	Acid phos., 480 lbs.; mur. potash, 120 lbs.; nit. soda, 240 lbs.	30	50	38
13	Acid phos., 720 lbs.; mur. potash, 180 lbs.; nit. soda, 240 lbs.	45	75	38
14	None	..	..	..
15	Acid phos., 480 lbs.; mur. potash, 180 lbs.; nit. soda, 360 lbs.	30	75	57
16	Acid phos., 480 lbs.; mur. potash, 180 lbs.; sulph. ammonia, 180 lbs.	30	75	38
17	None	..	..	..
18	Acid phos., 60 lbs.; Tankage (7-20) 670 lbs.; muriate potash, 180 lbs.	30	75	38
19	Acid phos., 320 lbs.; mur. potash, 180 lbs.; nit. soda, 240 lbs.	20	75	38
20	None	..	..	..
21	None	..	..	..
22	Acid phos., 480 lbs.; nitrate potash, 200 lbs.; nit. soda, 80 lbs.	30	75	38
23	Acid phos., 480 lbs.; sulphate potash, 190 lbs.; nit. soda, 240 lbs.	30	75	38
24	None	..	..	..
25	Acid phos., 480 lbs.; sul. potash, 190 lbs.; nit. soda, 240 lbs.; lime 1000 lbs.	30	75	38
26	Acid phos., 480 lbs.; mur. potash, 180 lbs.; nit. soda, 240 lbs.; lime 1000 lbs.	30	75	38
27	None	..	..	..
28	Acid phos., 480 lbs.; mur. potash, 180 lbs.; sul. am., 180 lbs.; lime 1000 lbs.	30	75	38
29	Acid phos., 60 lbs.; tankage (7-20) 670 lbs.; mur. pot., 180 lbs.; lime 1000 lbs.	30	75	38
30	None	..	..	..
31	None	..	..	..
32	Shed manure, untreated, 10 tons.	..	..	..
33	Shed manure, untreated, 20 tons.	..	..	..
34	None	..	..	..
35	Shed manure, phosphated, 10 tons.	..	..	..
36	Yard manure, phosphated, 10 tons.	..	..	..
37	None	..	..	..
38	Shed manure, untreated, 10 tons; lime, 1000 lbs.	..	..	..
39	Yard manure, untreated, 10 tons; lime, 1000 lbs.	..	..	..
40	None	..	..	..

The plots employed in this test are 16 feet wide by 136 feet long, containing one-twentieth acre each. They are separated by paths two feet wide and tile drains are laid under alternate paths, making the drains 36 feet apart. The plots are arranged in blocks of ten plots each and in three sections, A, B and C, of 40 plots each, as indicated by the diagrams, and every third plot is left continuously untreated.

The increase due to treatment is calculated on the assumption that if Plots 1 and 4, untreated, were to yield 300 and 330 pounds respectively, the unaided yields of Plots 2 and 3 would probably have been 310 and 320 pounds.

Section A is located on a small farm of 13 acres, which had been owned separately from the tract on which B and C are located before the land was leased by the Experiment Station.

In Table IV is given the average increase per acre for each crop over the entire period of the experiment with its value, rating tobacco at eight cents per pound for the wrapper and filler and one and one-half cent for the trash; wheat at 80 cents per bushel; straw at \$2.00 per ton, and hay at \$8.00. This table also shows the cost of the fertilizing, rating 14 percent acid phosphate at \$16.00 per ton; muriate of potash at two and one-half cents per pound, and nitrate of soda at three cents, and estimating the cost of potassium in the sulphate as 20 percent greater than in the muriate. The cost of nitrogen is assumed to be the same in nitrate of soda, nitrate of potash and sulphate of ammonia. The tankage used in the test is computed at \$28.00 per ton. Lime is figured at \$6.00 per ton. No values are placed upon the manure, as the cost of manure varies for each farm

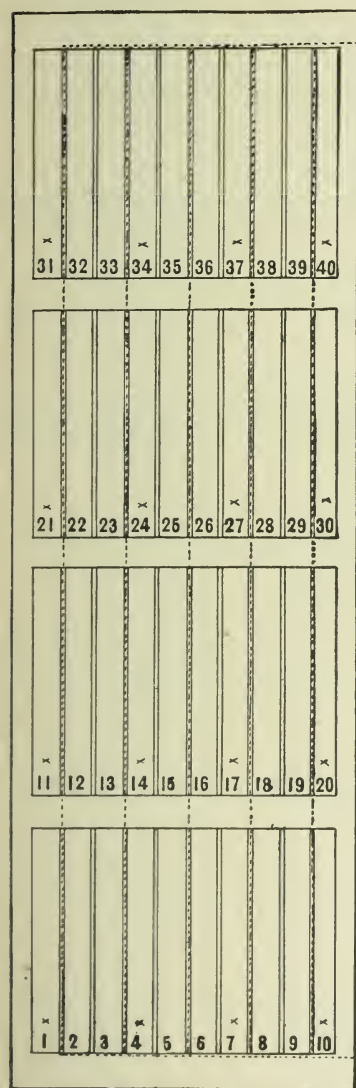


DIAGRAM II: Arrangement of plots in tobacco-wheat-clover rotation.
Sections B and C.

and for different parts of the same farm, owing to the distance from the barn. The phosphated manure has been dusted with floats applied at the rate of 40 to 50 pounds per ton of manure, equivalent to one pound per 1000-pound animal per day.

TABLE II: TOBACCO-WHEAT-CLOVER ROTATION. STATISTICS OF YIELD FOR 1907 AND 1908

Plot	Tobacco				Wheat				Clover hay	
	1907				1908				1907	1908
	Wrapper and filler	Trash	Total	Wrapper and filler	Trash	Total	Grain	Straw		
No.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Bus.	Lbs.	Lbs.	Lbs.
1	605	140	745	395	150	545	19.78	2,133	2,000	3,000
2	970	180	1,150	640	200	840	22.92	2,403	3,755	4,480
3	1,280	150	1,430	1,020	180	1,200	24.43	2,643	3,760	4,460
4	530	130	660	530	130	660	22.90	2,604	2,627	5,080
5	1,300	130	1,430	1,175	140	720	26.44	3,175	2,430	2,520
6	1,300	130	1,430	835	190	1,025	26.03	2,904	5,835	2,940
7	635	120	755	1,185	170	1,355	18.55	2,107	2,315	2,100
8	1,460	160	1,620	1,040	210	1,250	22.50	2,897	2,960	2,640
9	1,380	160	1,540	1,040	170	1,210	22.58	2,904	3,350	5,020
10	480	145	625	305	140	445	26.43	2,904	3,225	2,860
11	425	135	560	345	140	485	19.43	2,972	1,900	2,300
12	1,205	140	1,345	1,170	140	1,310	21.09	2,917	1,760	2,320
13	1,425	120	1,545	1,240	170	1,410	27.05	2,917	3,400	2,400
14	360	125	485	1,380	130	1,510	23.75	2,624	3,985	4,380
15	1,290	130	1,420	1,085	160	1,245	30.12	2,433	1,965	6,020
16	1,135	140	1,275	1,030	140	1,170	27.58	2,433	1,045	3,340
17	355	120	475	350	130	480	23.72	3,096	1,900	2,400
18	1,100	130	1,230	885	170	1,055	30.75	3,315	3,765	3,620
19	1,040	130	1,170	1,020	160	1,180	27.18	2,350	2,720	4,640
20	275	100	375	380	155	535	20.26	2,185	1,435	3,000
21	465	140	605	460	140	600	16.69	1,800	7.83	4,440
22	1,170	150	1,320	1,070	180	1,250	25.86	2,785	3,585	3,240
23	1,180	170	1,350	1,085	185	1,270	26.46	2,852	3,585	4,440
24	340	120	460	615	170	785	18.23	1,966	1,190	4,440
25	1,100	160	1,260	1,070	160	1,230	26.22	2,827	3,445	2,200
26	1,195	145	1,340	1,120	180	1,300	27.53	2,968	3,740	4,180
27	375	135	510	485	150	635	17.88	1,927	1,365	1,980
28	1,120	160	1,280	1,135	110	1,245	24.91	2,685	3,530	4,680
29	1,175	150	1,325	1,090	160	1,250	27.16	2,930	3,620	4,400
30	550	160	710	385	150	535	17.04	1,838	1,700	2,090
31	680	120	800	330	120	450	15.61	1,683	1,670	2,240
32	1,340	120	1,460	720	130	850	29.08	3,135	2,905	1,700
33	1,330	170	1,500	915	170	1,085	16.92	3,135	2,960	3,420
34	550	130	680	350	140	490	37.31	4,022	3,460	5,040
35	1,135	125	1,260	840	155	995	18.71	2,017	1,060	2,250
36	1,120	120	1,240	620	140	760	23.42	2,930	3,575	3,340
37	475	140	615	380	120	500	21.08	3,315	3,335	2,620
38	930	110	1,040	590	140	730	17.16	1,850	1,540	4,380
39	540	120	660	500	150	650	16.75	3,006	2,760	1,960
40	365	130	495	300	115	415	27.89	3,212	2,415	3,360
*	469	132	601	414	140	554	18.24	1,966	1,640	1,740
							19.27	2,077	1,691	2,449
							8.99			

TABLE III: TOBACCO-WHEAT-CLOVER ROTATION: AVERAGE YIELDS BY PERIODS.

Plot	Tobacco										Wheat		Clover	Plot
	First rotation—1903-5					Second rotation—1906-8					5-year average, 1904-8			
	Wrapper and filler	Trash	Total	Wrapper and filler	Trash	Total	Wrapper and filler	Trash	Total	Grain	Straw			
No.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Bu.	Lbs.	Lbs.	No.	
1	500	136	636	497	163	660	498	150	648	12 08	1 694	2 585	1	
2	650	187	837	598	208	806	728	198	926	18 45	2 560	3 335	2	
3	917	160	1 077	1 110	177	1 287	1 015	169	1 182	20 63	2 743	3 910	3	
4	450	157	607	493	154	647	1 182	156	1 338	11 72	1 622	2 370	4	
5	787	130	917	770	167	937	778	149	927	18 46	2 249	3 190	5	
6	910	190	1 100	1 097	196	1 293	999	193	1 192	22 89	2 926	4 020	6	
7	507	140	647	568	163	732	1 141	160	1 302	13 38	1 741	2 485	7	
8	983	137	1 120	1 298	177	1 475	1 141	155	1 296	23 42	2 890	4 160	8	
9	968	157	1 125	1 117	223	1 340	1 079	190	1 269	23 56	2 749	4 160	9	
10	423	140	563	502	168	670	462	154	616	12 70	1 598	2 195	10	
11	388	117	505	457	168	625	422	143	565	12 08	1 639	2 750	11	
12	857	170	1 027	1 198	160	1 358	1 027	165	1 192	23 98	2 949	3 875	12	
13	972	197	1 170	1 337	167	1 503	1 154	182	1 336	27 04	3 178	4 745	13	
14	397	127	523	457	138	595	427	132	559	12 04	1 565	2 425	14	
15	1 010	150	1 160	1 252	147	1 398	1 131	148	1 279	26 27	3 011	4 053	15	
16	963	150	1 113	1 185	163	1 348	1 074	157	1 231	23 83	2 798	3 885	16	
17	347	123	470	442	157	598	394	140	534	11 35	1 507	2 515	17	
18	647	113	760	995	180	1 175	821	147	968	24 26	2 747	3 995	18	
19	282	127	409	1 000	177	1 177	936	152	1 088	24 26	2 778	3 860	19	
20	454	120	574	430	158	588	358	139	497	10 43	1 278	2 470	20	
21	870	163	1 033	1 067	210	1 277	958	127	1 085	11 13	1 388	2 465	21	
22	870	170	1 040	1 112	187	1 298	991	178	1 169	22 65	2 820	3 615	22	
23	440	127	567	508	143	610	474	135	609	10 24	1 229	2 050	23	
24	913	153	1 067	1 104	177	1 283	1 010	165	1 175	22 98	2 645	3 435	24	
25	904	133	1 037	1 087	188	1 275	1 042	161	1 203	23 51	2 701	3 560	25	
26	853	137	990	1 122	148	1 270	1 017	142	1 165	10 90	1 302	3 865	26	
27	873	134	1 007	1 162	177	1 348	1 017	155	1 172	24 18	2 690	3 580	27	
28	693	120	813	1 093	147	1 270	893	149	1 042	19 67	2 232	3 710	28	
29	320	113	433	1 093	143	1 270	989	128	1 117	11 27	1 336	1 800	29	
30	404	116	520	453	133	610	470	125	595	10 53	1 296	1 845	30	
31	793	113	907	519	137	670	470	125	595	10 53	1 296	1 845	31	
32	753	113	866	993	137	1 130	893	125	1 018	21 88	2 691	3 185	32	
33	327	133	460	1 218	167	1 385	985	150	1 136	26 27	3 112	3 995	33	
34	317	133	450	1 040	140	1 200	428	137	565	10 42	1 227	2 055	34	
35	787	140	927	1 040	160	1 200	893	150	1 043	23 10	2 662	3 940	35	
36	530	113	643	1 083	137	1 220	895	125	1 020	22 72	2 749	3 655	36	
37	750	123	873	1 480	133	1 613	405	123	528	9 91	1 325	1 875	37	
38	803	153	956	1 092	137	1 229	837	130	967	21 16	2 586	3 035	38	
39	300	117	417	752	150	902	788	142	930	19 01	2 287	3 180	39	
40	392	129	522	482	142	624	368	129	497	8 98	1 152	1 620	40	
*	392	129	522	482	149	631	437	139	576	11 25	1 432	2 211	*	

* Average unfertilized yield.

The fertilizers and manures are all applied to the tobacco, the wheat and clover following without any treatment.

Comparing the increase on the first five fertilized plots, as given in Table IV, we find that each application of fertilizers has produced a profitable increase of crop, but the gain from the complete fertilizer, as applied on Plot 8, carrying nitrogen, phosphorus and potassium, all three, has been so much greater than that from any partial fertilizer, as to more than offset the greatly increased cost, so that the largest net gain has resulted from this application.

When the potassium in this fertilizer is increased, on Plot 9, the total tobacco yield remains the same, while that of wheat and hay are slightly increased; but while the total tobacco yield is stationary, there appears to have been a small transfer from the valuable parts of the plant to those less valuable and the consequence is a slight reduction in the total value of the output, and of course a greater one in the net value.

On the other hand, the reduction of the potassium, on Plot 12, results in a falling off in yield sufficient to more than neutralize the saving in the cost of the fertilizer, and a still greater loss occurs when it is entirely omitted, on Plot 6.

When sulphate of potash is substituted for the muriate, on Plot 23, there is a reduction in yield, as compared with Plot 8; and as the sulphate is more expensive than the muriate there is a still greater reduction in the net gain.

This comparison of sulphate with muriate of potash is repeated on two limed plots, numbers 25 and 26, and here again the sulphate falls behind the muriate in total yield and net gain, the loss being chiefly in the tobacco, as the wheat shows a small gain.

The substitution of the nitrate of potash, on Plot 22, has been followed by a still greater reduction in yield.

When the phosphorus is increased, on Plot 13, there is a marked gain in yield, this plot producing a greater total yield and a greater net gain than any other one in the series; while the reduction of the phosphorus, on Plot 19, is followed by a reduction in net gain as well as in total yield.

The increase of the nitrogen, on Plot 15, brings up the total yield to the second highest point in the series, and notwithstanding the high cost of nitrogen in nitrate of soda, this plot also gives next to the highest net gain. Comparing Plot 3, which receives phosphorus and potassium, but no nitrogen, with Plots 8 and 15, which receive the same quantities of phosphorus and potassium, in the

same carriers, reinforced with 240 pounds of nitrate of soda on Plot 8 and 360 pounds on Plot 15, it will be seen that the total gain is increased from \$56.82 on Plot 3 to \$66.62 on Plot 8 and \$76.75 on Plot 15.

Comparing nitrate of soda with sulphate of ammonia as carriers of nitrogen, on Plots 8 and 16, and again with lime, on Plots 26 and 28, there is an apparent gain for the sulphate of ammonia in each case.

When nitrogen and phosphorus are given in tankage, on Plots 18 and 29, there is so great a reduction in the yield of tobacco as to much more than offset the small saving in the cost of the fertilizer. As tankage is the carrier of nitrogen usually employed in ready-mixed fertilizers this becomes an important point, the more so as the farmer generally pays more for the pound of nitrogen in such fertilizers than he would need to pay in nitrate of soda.

The manure used in this experiment for the first rotation was horse manure; since then it has come from cattle, but in both cases it has accumulated on earth floors. Theoretically, ten tons of such manure should contain, when unleached, 75 to 80 pounds each of nitrogen and potassium and 25 to 30 of phosphorus. On this basis the constituents of the manure have not been quite as effective, pound for pound, as the same constituents in the chemical fertilizer. It will be observed, however, that when the manure has been used at the rate of 10 tons per acre it has produced increase to the average value of more than \$5.00 per ton of manure.

Comparing Plots 32 and 35 it appears that the reinforcement of the manure with phosphorus (in the form of floats, and at the rate of approximately 40 pounds to the ton of manure) has materially increased its effectiveness. When thus treated there has been no practical difference in the effect of the yard and shed manure, but when both kinds of manure, untreated, have been followed by lime there has been a considerable superiority in the unleached manure.

EFFECT OF LIME.

The effect of lime is shown in Table V, in which are contrasted the yields of 5 pairs of plots, which are treated alike in all respects except the use of lime. Apparently lime is not yet needed on this soil for the crops grown in this experiment, the soil being chiefly derived from decomposition of limestone and limestone gravels.

Fertilizing material	Pounds of essential constituents		
	Ammonia Lbs.	Phosphoric acid Lbs.	Potash Lbs.
Nitrate of soda, 240 lbs.....	45	....	....
Acid phosphate, 720 lbs.....	....	100	....
Muriate of potash, 180 lbs.....	....	....	90
Total 1140 lbs.....	45	100	90
Percentage	4	9	8

TABLE V: EFFECT OF LIME ON TOBACCO, WHEAT AND CLOVER, GROWN IN ROTATION

Plot	Treatment	Average increase per acre			Value of Increase	
		To- bacco	Wheat	Hay	Total	Net
No.		Lbs.	Bus.	Lbs.	\$	\$
8	Acid phosphate, muriate potash, nitrate soda.....	624	10.26	1,772	66.62	51.02
26	" " " lime.....	618	12.83	1,633	66.39	47.79
23	Acid phosphate, sulphate potash, nitrate soda.....	563	12.11	1,592	59.83	43.33
25	" " " lime..	578	12.52	1,446	62.00	42.50
16	Acid phoshate, muriate potash, sulphate ammonia.....	688	12.25	1,400	70.46	54.86
28	" " " lime.....	618	13.16	1,837	67.58	48.98
18	Tankage, muriate potash.....	445	13.17	1,495	52.97	39.07
29	" " " lime.....	506	8.52	1,888	54.71	37.81
32	Untreated shed manure.....	434	11.39	1,270	50.52	
38	" " " lime.....	443	11.56	1,242	51.04	

Following is the plan of fertilizing in this test, the quantities being pounds per acre:

Plot 1, None

" 2, Acid phosphate,	160 lbs;	muriate potash,	60 lbs.;	nitrate soda,	80 lbs.
" 3, " "	160 "	" "	60 "	" "	160 "
" 4, None					
" 5, Acid phosphate,	160 lbs;	muriate potash,	60 lbs.;	nitrate soda,	320 lbs.
" 6, " "	160 "	" "	60 "	" "	480 "
" 7, None					
" 8, Acid phosphate,	320 lbs;	muriate potash,	60 lbs.;	nitrate soda	320 lbs.
" 9, " "	320 "	" "	120 "	" "	320 "
" 10, None					

Plots 11 to 18, inclusive, are cross dressed with untreated shed manure, 8 tons per acre. The following additional treatment is given:

Plot 11, None.

" 12, Acid phosphate,	160 lbs.
" 13, Acid phosphate,	160 lbs.; muriate potash, 60 lbs.; nitrate soda, 160 lbs.
" 14, None.	
" 15, Acid phosphate,	160 lbs.; muriate potash, 60 lbs.; nitrate soda, 320 lbs.
" 16, Phosphated shed manure,	5 tons.
" 17, None.	
" 18, Phosphated yard manure,	5 tons.

Table VI gives the statistics of this experiment for 1906, 1907, and 1908 (continuing the record from Bulletin 172) with averages by periods, and the results are summarized in Table VII.

The cost of fertilizers, value of increase and net gain are computed annually in Table VII, whereas they are computed for each rotation of 3 years in Table III. In Table VIII the results of similar treatment are compared for the two 3-year periods during which the experiment has been in progress. This table shows that under each similar method of treatment there has not only been a smaller yield in the tobacco grown continuously than in that grown in rotation, which indeed is to be expected, since the rotated tobacco gets larger applications of fertilizer and manure than that grown continuously, but that the rotated tobacco has increased in yield during the second period, as compared with the first, whereas that grown continuously has fallen off in yield in every case except on Plot 2, and there the gain has been very small. Reference to Table VI will show that even on the very heavily fertilized and manured plots in the continuous culture there has been a reduction in yield during the second period, as compared with the first.

TABLE VI: STATISTICS OF PRODUCTION OF TOBACCO GROWN CONTINUOUSLY, 1903 TO 1908.

Yield per acre																		
Plot	1906			1907			1908			3-year average, 1903-5			3-year average, 1906-8			6-year average, 1903-8		
	Wrapper and filler	Trash	Total	Wrapper and filler	Trash	Total	Wrapper and filler	Trash	Total	Wrapper and filler	Trash	Total	Wrapper and filler	Trash	Total	Wrapper and filler	Trash	Total
No.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
1	380	220	600	190	100	290	225	150	375	355	130	485	265	157	422	311	143	453
2	850	220	1,070	560	140	700	650	130	780	663	150	813	687	163	850	675	157	832
3	980	200	1,180	545	140	685	575	130	705	763	163	926	700	163	863	732	157	887
4	420	180	600	235	120	355	210	120	330	317	163	480	288	140	428	302	152	454
5	1,030	240	1,270	730	150	880	740	140	880	806	167	973	833	177	1,010	820	172	992
6	1,125	220	1,345	745	140	885	680	140	820	763	164	927	850	167	1,017	807	165	972
7	1,280	170	1,450	820	95	915	805	135	940	837	133	970	897	133	1,030	820	127	917
8	1,160	220	1,380	820	160	980	805	130	935	887	143	1,030	928	170	1,098	882	182	1,064
9	1,330	180	1,510	880	150	1,030	875	130	1,005	963	147	1,110	1,028	160	1,188	986	153	1,149
10	1,240	120	1,360	140	90	230	165	140	305	210	110	320	182	117	299	196	113	309
*	330	172	502	182	101	283	186	136	322	296	131	427	233	137	370	265	134	399
Cross dressed with untreated manure, 8 tons per acre																		
11	850	130	980	500	140	640	595	125	720	760	280	1,040	648	132	780	738	159	897
12	955	170	1,125	725	155	880	760	135	895	720	290	1,010	813	160	973	803	183	986
13	1,280	180	1,460	940	180	1,120	890	130	1,020	1,030	260	1,290	945	160	1,105	1,006	172	1,178
14	1,070	140	1,210	1,020	140	1,160	615	120	735	1,080	260	1,340	742	133	875	800	137	936
15	1,350	140	1,490	1,025	130	1,155	1,175	110	1,050	1,320	230	1,550	1,103	133	1,236	1,100	132	1,232
16	1,400	130	1,530	1,025	130	1,155	1,040	110	1,150	1,230	220	1,450	1,135	130	1,265	1,121	145	1,266
17	1,160	200	1,360	830	160	990	865	135	1,000	940	270	1,210	952	165	1,117	909	189	1,098
18	1,280	180	1,460	1,160	140	1,300	1,010	135	1,145	1,120	260	1,380	1,153	152	1,305	1,103	161	1,264
**	1027	157	1,183	623	147	770	692	127	819	897	270	1,167	781	143	924	819	162	931
Increase per acre																		
2	457	13	470	355	33	388	430	-10	420	373	-63	310	414	12	426	367	11	378
3	573	7	580	325	27	352	360	20	380	547	-107	440	419	18	437	427	6	433
5	656	64	720	518	38	556	551	15	566	575	-40	560	575	39	614	535	28	563
6	789	47	836	557	37	594	514	10	524	690	.....	560	623	32	635	539	30	569
8	893	67	960	664	67	731	663	-7	656	673	127	800	740	42	782	652	39	711
9	1,077	43	1,120	731	58	789	717	12	729	877	-7	870	842	38	880	782	35	817
12	32	37	69	211	15	226	158	32	190	113	110	-3	134	28	162	42	32	74
13	283	43	326	414	40	454	240	28	270	137	60	197	313	37	350	221	28	249
15	280	-20	260	383	3	386	242	-15	227	346	.....	346	891	-37	854	257	-2	255
16	270	-50	220	290	292	289	238	-20	238	274	.....	184	820	-27	747	245	-27	218
18	130	-20	110	330	-20	310	145	-20	145	180	-110	70	202	-13	189	194	-2	166

* A average unfertilized yield.

** A average yield of plots receiving manure only, 8 tons per acre.

TABLE VII: TOBACCO GROWN CONTINUOUSLY: SUMMARY OF RESULTS FOR 6 YEARS.

Plot No.	Treatment	Cost of fertilizers	Value of Increase	Net gain
2	Acid phosphate, 160 lbs.; muriate potash, 60 lbs.; nitrate soda, 80 lbs.	\$ 5.20	\$ 20.52	\$ 24.34
3	" " " " " " " " " " " "	7.60	34.45	26.85
5	" " " " " " " " " " " "	12.40	43.22	31.82
6	" " " " " " " " " " " "	17.20	43.77	26.57
8	" " " " " " " " " " " "	13.70	53.05	39.35
9	" " " " " " " " " " " "	15.20	63.08	47.88
11-14-17	8 tons manure.....	.....	44.74	.....
12	" " " " " " " " " " " "	1.30	48.68	.....
13	" " " " " " " " " " " "	7.60	62.94	.....
15	" " " " " " " " " " " "	12.40	65.37	.....
16	" " " " " " " " " " " "	1.30	63.54	.....
18	" " " " " " " " " " " "	1.30	69.74	.....

TABLE VIII: COMPARISON OF YIELDS OF TOBACCO PER ACRE
IN CONTINUOUS AND ROTATIVE CROPPING.

Treatment			First period, 1903-5			Second period, 1906-8		
Fertilizers per acre per period	Cropping	Plot	Wrapper and filler	Trash	Total	Wrapper and filler	Trash	Total
			Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
None	Rotative..... Continuous..	No. a b	333 296	129 131	522 427	482 253	149 137	631 370
Acid phosphate, 480 lbs.; muriate potash, { 180 lbs.; nitrate soda, 240 lbs.	Rotative..... Continuous..	8 2	983 663	133 150	1,117 813	1,298 687	177 163	1,475 850
Acid phos., 480 lbs.; mur. potash, 180 lbs.; nit. soda, 360 lbs..... 480 " " 180 " " 480 " "	Rotative..... Continuous..	15 3	1,010 763	150 147	1,160 910	1,252 700	147 163	1,398 863
Untreated shed manure, 20 tons..... " " 24 "	Rotative..... Continuous..	33 c	753 587	133 270	887 1,167	1,218 781	167 143	1,385 924

a Average of all unfertilized plots.

b Average of Plots 1, 4, 7 and 10.

c Average of Plots 11, 14 and 17.

III. FERTILIZERS AND MANURE ON CORN AND WHEAT GROWN IN ROTATION WITH CLOVER.

The plan of this cereal rotation is shown in Table IX. The statistics for the first 3 years of the experiment, 1905 to 1906, inclusive, are given in Bulletin 184, and those for 1907 and 1908 follow in Table X, while Table XI is a summary of the results for the entire period of the experiment.

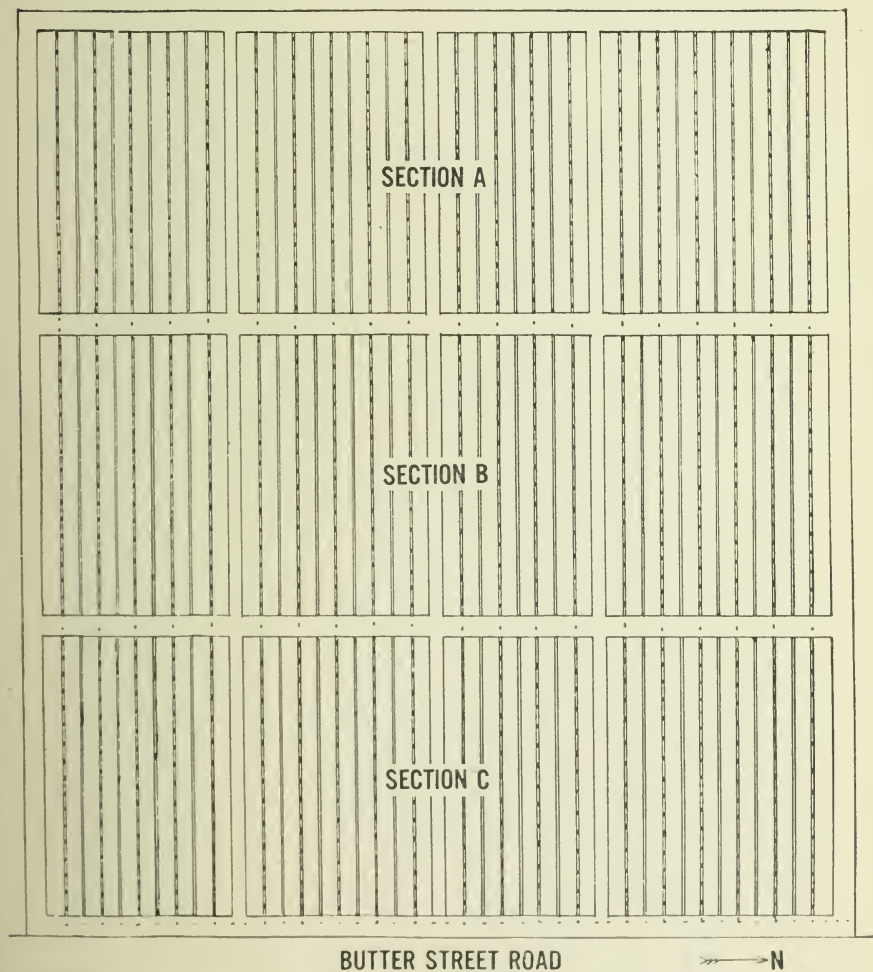
TABLE IX: PLAN OF FERTILIZING IN CORN-WHEAT-CLOVER ROTATION
AT THE GERMANTOWN TEST-FARM.

Plot No.	Fertilizing materials—pounds per acre							Fertilizing elements—pounds per acre.			
	On corn			On Wheat				Total fertilizers for one rotation	Phosphorus	Potassium	Nitrogen
	Acid phosphate	Muriate of potash	Nitrate of soda	Acid phosphate	Muriate of potash	Dried Blood	Nitrate of soda				
1	....	....	....	....	....	....	....	....	....	....	....
2	120	....	....	120	....	....	....	240	15	....	....
3	120	20	....	120	20	....	....	280	15	16½	....
4	....	....	....	....	....	....	....	....	....	....	....
5	....	20	80	....	20	30	60	210	....	16½	25½
6	120	....	80	120	....	30	60	410	15	....	25½
7	....	....	....	....	....	....	....	....	....	....	....
8	120	20	80	120	20	30	60	450	15	16½	25½
9	120	20	160	120	20	30	140	610	15	16½	50½
10	....	....	....	....	....	....	....	....	....	....	....
11	120	40	160	120	40	30	140	650	15	33	25½
12	240	20	80	240	20	30	60	710	30	16½	25½
13	....	....	....	....	....	....	....	....	....	....	....
14	240	40	160	240	40	30	140	890	30	33	50½
15	480	80	320	Lime, 1,000 pounds				890	30	33	50½
16	Untreated shed manure 5 tons on corn; lime, 1,000 lbs. on wheat.										
17	Untreated shed manure 10 tons, 1904-5-6; lime, 1,000 lbs., 1907-8-9; manure and lime on corn only.										
18	.....										
19	Untreated shed manure 10 tons, 1903-4-5; lime 1,000 lbs., 1906-7-8; manure and lime on wheat only										
20	.....										
21	Lime, 1,000 lbs. on corn; untreated shed manure, 5 tons on wheat.										
22	Unfertilized.										
23	Untreated yard manure 5 tons, on corn only.										
24	Untreated shed manure, 5 tons, on corn only.										
25	Unfertilized.										
26	Phosphated yard manure, 5 tons on corn only.										
27	Phosphated shed manure, 5 tons on corn only.										
28	Unfertilized.										
29	Phosphated shed manure, 5 tons on corn; lime, 1000 lbs. on wheat.										
30	Tankage, 680 lbs; muriate of potash, 80 lbs; nitrate of soda, 80 lbs. on corn; lime, 1,000 lbs. on wheat.										
31	Unfertilized.										
32	Tankage, 340 lbs; muriate of potash, 40 lbs; nitrate of soda, 40 lbs; on corn; same on wheat.										
33	Tankage, 340 lbs; muriate of potash, 60 lbs; nitrate of soda, 120 lbs. on corn; same on wheat.										
34	Unfertilized.										
35	Tankage, 220 lbs; acid phos., 200 lbs; muriate of potash, 20 lbs. on corn; same on wheat.										
36	Tankage, 220 lbs; acid phos., 200 lbs; muriate of potash, 40 lbs; nitrate of soda, 80 lbs. on corn; same on wheat.										
37	Unfertilized.										
38	Tankage, 500 lbs; muriate of potash, 60 lbs; nitrate of soda, 60 lbs. on corn; same on wheat.										
39	Tankage, 170 lbs; nitrate of soda, 18 lbs. on corn; same on wheat,										
40	Unfertilized.										

Table XI shows that acid phosphate, when used alone at the rate of 120 pounds per acre each on corn and wheat, has produced a profitable increase in each crop, as well as in the clover following, the total value of the increase amounting to more than 4 times the cost of the fertilizer.

When the very small quantity of 20 pounds per acre of muriate of potash is added to this dressing of acid phosphate the total and net gain are largely increased, and that this increase is not due to accidental variations in the soil is indicated by comparing Plot 6, which receives nitrate of soda and acid phosphate, but no potash, with Plot 8, which receives the same quantities of nitrate of soda and acid phosphate, with 20 pounds of muriate of potash in addition. It seems evident, therefore, that both phosphorus and potassium are needed in the fertilizer to produce the best results on this soil.

DIAGRAM III: ARRANGEMENT OF PLOTS IN CORN-WHEAT-CLOVER ROTATION



Plots are numbered from left to right in each section. Dotted lines indicate tile drains.

That nitrogen also is needed is seen by comparing Plot 6, receiving nitrogen and phosphorus, with Plot 2, receiving phosphorus only; or by comparing Plot 8, receiving nitrogen, phosphorus and potassium, with Plot 3, receiving phosphorus and potassium only. It is true that the net gain is not as large on Plot 8 as on Plot 3, owing to the high cost of fertilizer nitrogen; but when we increase the proportion of phosphorus to nitrogen, on Plot 12, we get a larger net gain than on any other combination of fertilizing materials used in the experiment. It is true that a somewhat larger total increase has been secured on Plots 14 and 33, receiving more nitrogen, but the extra cost of the fertilizer has outrun the value of the increase on these plots.

TABLE X: CORN-WHEAT-CLOVER ROTATION:—STATISTICS OF
YIELD FOR 1907 AND 1908.

Plot	Corn				Wheat				Clover	
	Grain		Stover		Grain		Straw		Hay	
	1907	1908	1907	1908	1907	1908	1907	1908	1907	1908
No.	Bus.	Bus.	Lbs.	Lbs.	Bus.	Bus.	Lbs.	Lbs.	Lbs.	Lbs.
1	58.14	28.57	3,100	2,400	12.33	9.83	1,330	1,720	2,310	1,470
2	65.71	33.14	3,410	2,580	15.08	14.42	1,625	2,375	2,750	2,290
3	73.43	42.14	3,900	2,990	20.50	15.00	2,210	2,510	3,110	2,480
4	59.71	32.43	3,190	2,410	14.18	12.83	1,529	2,110	2,900	1,550
5	61.29	39.14	3,410	2,710	15.08	12.87	1,625	2,217	2,820	1,620
6	60.29	40.14	3,210	2,900	19.79	15.79	2,133	2,762	3,550	2,300
7	46.86	40.57	2,600	2,750	11.32	10.12	1,221	1,782	3,160	1,390
8	63.57	52.43	3,540	3,080	21.16	15.08	2,280	2,665	3,350	2,430
9	66.86	55.57	3,680	3,280	21.21	15.79	2,287	2,792	3,190	2,350
10	44.57	49.71	2,760	2,950	11.44	10.70	1,234	1,685	3,240	1,290
11	80.71	61.86	4,580	3,620	21.99	17.17	2,371	2,840	3,820	2,520
12	77.71	66.00	4,800	3,780	23.95	17.00	2,583	2,630	3,780	3,860
13	63.86	52.00	3,630	3,240	13.64	10.92	1,472	1,645	3,030	1,390
14	81.86	63.71	5,120	3,800	25.03	18.04	2,698	2,967	3,750	4,100
15	84.00	52.43	5,770	3,850	21.81	14.83	2,351	2,240	3,780	2,630
16	50.43	39.71	3,170	2,550	13.94	9.17	1,504	1,390	2,670	1,670
17	70.71	56.14	4,700	3,720	19.43	12.83	2,094	2,080	3,960	2,760
18	71.57	50.00	4,790	3,300	19.07	11.04	2,056	1,857	3,820	2,330
19	60.86	46.14	3,850	2,920	14.84	10.37	1,600	1,557	3,270	1,630
20	70.29	44.57	4,410	2,750	21.69	10.21	2,339	1,687	3,770	2,990
21	60.29	38.14	3,560	2,550	23.30	12.96	2,512	2,152	3,440	3,090
22	45.71	35.86	2,900	2,460	15.14	7.21	1,632	1,267	3,160	1,760
23	53.43	41.00	3,110	2,420	18.42	8.21	1,985	1,437	3,760	2,060
24	61.71	46.71	3,650	2,720	20.08	10.62	2,165	1,792	4,070	2,140
25	37.57	32.29	2,510	2,280	13.82	6.21	1,491	1,267	3,010	1,800
26	60.43	41.71	3,350	2,700	18.59	13.00	2,005	2,190	3,350	1,920
27	75.00	49.00	4,250	2,660	16.51	13.04	1,779	1,967	3,590	2,130
28	68.57	40.00	3,690	2,530	10.91	7.67	1,175	1,510	3,030	1,520
29	81.00	47.29	5,100	3,100	18.30	15.29	1,972	2,392	3,780	2,460
30	81.71	58.00	5,010	3,450	22.47	12.17	2,422	2,250	4,170	3,390
31	51.71	41.86	3,050	2,610	17.34	7.17	1,869	1,530	3,320	2,490
32	63.14	56.29	3,360	3,360	29.38	14.17	3,167	2,670	4,120	4,750
33	66.86	53.29	4,150	3,290	31.23	15.54	3,366	2,967	4,230	4,800
34	33.43	33.71	2,250	2,520	21.93	5.17	2,364	1,160	2,830	3,700
35	59.29	47.71	3,150	2,790	29.92	14.50	3,225	2,480	3,600	5,600
36	64.43	45.71	3,780	2,690	29.50	15.37	3,180	2,657	3,590	5,470
37	48.43	26.86	2,900	2,560	21.21	4.58	2,287	825	2,090	3,850
38	66.14	44.57	4,330	2,960	26.46	11.83	2,852	1,890	3,800	5,270
39	60.43	27.43	3,600	1,950	18.95	6.75	2,043	1,155	2,350	3,610
40	59.71	25.29	4,100	1,850	14.66	4.42	1,580	835	1,880	2,050
*	52.11	37.50	3,121	2,501	14.84	8.31	1,592	1,449	2,850	1,969

*Average unfertilized yield.

TABLE XI: CORN-WHEAT-CLOVER ROTATION: AVERAGE INCREASE, COST OF FERTILIZERS AND NET GAIN PER ACRE, 1905 to 1908.

Plot	Fertilizing elements per acre			Average increase per acre				Cost of ferti- lizers	Value of increase	Net Gain	Plot No.	
	Phos- phorus	Potas- sium	Nitro- gen	Corn: 5-year av.		Wheat: 4 year av.						Clover 4-yr. av.
				Grain	Stover	Grain	Straw.					
Lbs.	Lbs.	Lbs.	Bus.	Lbs.	Bus.	Lbs.	\$	\$	\$	No.		
2	15	.....	.....	7.28	213	4.54	447	1.90	9.12	7.22	2	
3	15	16½	.....	11.31	494	5.90	614	2.90	13.23	10.33	3	
5	..	16½	25½	4.43	247	1.27	166	5.80	4.30	-1.50	5	
6	15	.....	25½	7.76	313	6.89	724	6.70	12.65	5.95	6	
8	15	16½	25½	12.21	479	7.65	849	7.70	15.51	7.81	8	
9	15	16½	50½	10.99	373	7.89	944	12.50	14.43	1.93	9	
11	15	33	25½	16.21	872	9.71	1,137	13.50	20.46	6.96	11	
12	30	16½	25½	15.99	850	10.43	1,165	9.60	22.49	12.89	12	
14	30	33	50½	17.37	862	12.61	1,464	15.40	24.15	8.75	14	
15	30	33	50½	18.34	1,336	6.52	1,736	17.90	18.18	.28	15	
17	..	.....	.....	16.91	1,013	4.28	744	.....	15.18	.....	17	
18	..	.....	.....	13.13	905	5.03	576	.....	13.47	.....	18	
20	..	.....	.....	13.03	621	5.07	532	.....	14.86	.....	20	
21	..	.....	.....	2.05	-14	3.34	414	.....	7.18	.....	21	
23	..	.....	.....	12.78	413	1.67	163	.....	8.37	.....	23	
24	..	.....	.....	19.16	701	5.15	535	.....	15.21	.....	24	
26	..	.....	.....	11.66	395	4.07	462	.....	9.55	.....	26	
27	..	.....	.....	13.23	525	3.52	330	.....	9.98	.....	27	
29	..	.....	.....	13.67	944	5.11	570	.....	13.48	.....	29	
30	30	33	50½	15.88	1,043	6.35	658	17.90	16.77	1.13	30	
32	30	33	50½	14.33	601	9.92	1,087	15.40	20.23	4.83	32	
33	30	50	75	15.76	916	11.47	1,294	21.20	22.62	1.42	33	
35	44	16½	25½	13.70	579	8.66	1,717	11.50	19.20	7.70	35	
36	44	33	50½	13.60	599	11.03	1,263	17.30	20.66	3.36	36	
38	44	50	75	14.15	799	10.15	1,068	22.10	20.53	-1.57	38	
39	15	.....	25½	3.36	-33	2.34	248	6.70	4.55	2.15	39	
Average unfertilized yield.....				45.84	2,648	10.7	1,316					

Plot 12 receives 160 pounds of nitrate of soda, carrying about 25 1-3 pounds of nitrogen, equivalent to 30 pounds of "ammonia;"* 480 pounds of 14 percent acid phosphate, carrying 30 pounds of phosphorus or 68 pounds of "phosphoric acid," and 40 pounds of muriate of potash, carrying 16 1-2 pounds of potassium or 20 pounds of "potash."

As fertilizers are ordinarily computed the percentage composition of this mixture would be approximately as below:

Carrier	Pounds of essential constituents		
	Ammonia	Phosphoric Acid	Potash
160 lbs. nitrate of soda.....	30	...	...
480 lbs. acid phosphate.....	...	68	...
40 lbs. muriate of potash.....	...	...	20
680 lbs. total.....	30	68	20
Percentage.....	4	10	3

Five tons of fresh manure, as used on Plot 24, should contain approximately the same quantities of nitrogen and phosphorus and about twice as much potassium as have been used on Plot 9. Comparing Plots 24 and 9 we see that the corn has made a larger increase on Plot 24 and the wheat and clover on Plot 9, the total value of the increase being slightly greater on Plot 24. Had Plot 24 received the same chemical fertilizers as Plot 9, but all in one application to the corn crop, the result would undoubtedly have been a larger increase in that crop and a smaller one in the wheat and clover, with probably a smaller total increase on all the crops (compare Plots 14 and 15, Table XI.) Hence it is fair to conclude that the chemical constituents of the fresh manure are producing practically the same effect as those in the chemicals. The results attained on the manured plots as a whole, however, are as yet inconclusive. The shed manure has been followed by a greater average increase than the yard manure, but the untreated manure has apparently produced a larger increase than that reenforced with floats, whether we compare Plot 17 with 29 or Plots 23 and 24 with 26 and 27. A careful analysis of the results, however, indicates that this outcome is largely due to inequalities in soil conditions which will probably be eliminated, in part at least, as the work progresses. It will be remembered that in these experiments there are as many separate tracts or sections of land as there

*Ammonia is a compound of nitrogen with hydrogen, containing about 82 percent nitrogen; phosphoric acid is a compound of phosphorus with oxygen, containing about 44 percent phosphorus, and potash is a compound of potassium with oxygen, containing nearly 84 percent potassium.

are crops in the rotation. In the one under consideration the corn crop, grown on Section A in 1904, yielded 30.14 bushels per acre for the untreated manure and 32.28 bushels for the phosphated manure. In 1907 the yields on the same land were 57.57 and 68.57 bushels, respectively, for the treated and untreated manure. In 1905 the yields on Section B were 72.00 for untreated and 62.78 for phosphated manure; but in 1908 the yields were 43.85 and 45.35 bushels, respectively, a reversal in both cases of more than 10 bushels per acre in the respective yields. Wheat was grown on Section A in 1905, and the yields, like those of the previous corn crop, were practically the same for the two kinds of manure; but in 1908 the yield for the phosphated manure was nearly 40 percent greater than for that not so treated.

These points illustrate the importance of long continued work on a systematic plan in dealing with such problems as this. On the one hand we have a soil which has been under cultivation for nearly a century and which has probably been subjected to differences in treatment of which we can have no knowledge, and on the other we have a fertilizing substance (floats) notoriously inert and slow in action.

This comparison is being duplicated in the tobacco rotation on the same farm, and here the results are consistent with those attained in the larger test at the main station, where the advantage of reenforcing farm manures with phosphorus is being strikingly demonstrated,* although in this test also the differences shown at the beginning of the work were much smaller than they have grown to be as the work has progressed.

On plots 30 to 39, inclusive, a part or all of the nitrogen and phosphorus is given in tankage, instead of nitrate of soda and acid phosphate. Comparing these with the plots receiving all their nitrogen and phosphorus in nitrate of soda and acid phosphate, it will be seen that tankage has not proved to be as effective a carrier as the other materials. This is a matter of considerable importance to the farmer, since the nitrogen in the ordinary, ready-mixed commercial fertilizer is derived chiefly from tankage.† In computing the cost of the fertilizer the tankage nitrogen is computed at the same price as that in nitrate of soda. In point of fact, the farmer usually pays more for the nitrogen carried in ready-mixed fertilizers than he would need to pay for it in nitrate of soda.

*See Circular 92, p. 25.

†The nitrogen in tankage is in organic form, and must be first converted into ammonia and then into nitric acid before it becomes available. The nitrogen of fresh manure is largely in the form of ammonia, hence it is well on the way towards availability.

Taking the 13 counties comprised in the two tiers lying north of those named, the yields for these two periods have been for corn, 30.1 bushels and 34.6 bushels, and for wheat, 11.7 bushels and 14.4 bushels, a gain of 4.5 bushels of corn and 2.7 bushels of wheat. These counties are now equalling the yields of the Miami Valley in corn and are exceeding their yields in wheat, and the richest region of the state has shifted from this fertile valley to the northwestern counties.

In the ripening of the grain crops about three-fourths of the total phosphorus of the plant is carried into the grain, while about three-fourths of the potassium remains in the straw. Consequently in all regions where grain is largely produced and sold off the farm ordinary soils soon show a deficiency of phosphorus, while in those regions in which not only the grain, but also the straw and hay are removed, both phosphorus and potassium are likely to be exhausted, and this condition applies to the lower Miami Valley; the paper mills and the tobacco warehouses, together with the urgent city demand for hay, having stripped the land of everything that could be carried away except the corn stalks, and that they were not also taken was only due to the fortunate circumstance that they were not adapted to paper making.

Under such conditions it is to be expected that potassium will occupy a position of larger relative importance in the fertilizer than for a region in which the system of agriculture has involved the deportation of grain and animal products chiefly, the straw and hay being retained on the land, and that it will be necessary to restore this element, as well as nitrogen and phosphorus, before maximum yields can be attained.

CONCLUSIONS.

These experiments must be carried much further before final conclusions can safely be drawn, but they have already demonstrated that the yield of crops may be greatly and profitably increased, on the upland soils of the Miami Valley, by the judicious use of manure or chemical fertilizers.

They show that the most effective manure is that which has not been subjected to the losses which occur in the open barnyard, and they indicate that the most effective fertilizer is one containing nitrogen, phosphorus and potassium, all three.

No urgent need of lime has as yet been developed in the soil under these experiments, and this was to be expected from its geological history. It has not yet been demonstrated, however, that moderate applications of lime may not be useful, especially upon those fields in this region which have been longest under cultivation.

PREFACE.

In this bulletin we seek to show the bearing, upon practical animal nutrition, of the relationship between those mineral elements of our foodstuffs and of living animal tissues, which in the body give rise to inorganic acids, and the various means at the disposal of the animal for accomplishing protection from these acids through effecting their neutralization.

The formation of inorganic acids from the food and from the tissues in the animal body, and the necessity for their neutralization, are always present, and therefore students of the effects of foodstuffs upon growth and other proteid increase in animals, must consider this factor in determining the causes of the results produced.

BULLETIN

OF THE

Ohio Agricultural Experiment Station

NUMBER 207.

AUGUST, 1909.

THE BALANCE BETWEEN INORGANIC ACIDS AND BASES IN ANIMAL NUTRITION.

BY E. B. FORBES.

INTRODUCTION.

The vital reactions taking place in the bodies of animals require that certain necessary conditions be maintained with unvarying constancy.

None of these conditions is of wider or deeper significance to these vital processes than the state of the liquids and tissues as regards acidity and alkalinity.

Nearly all of the mineral elements in the body contribute to one or the other side of this account and thus become involved in a great number of most important functions.

This balance between acid and alkaline mineral elements in animal bodies is constantly maintained in adjustment by a most intricate system of compensating agencies, so that, under normal conditions, the matter is perfectly accomplished without our conscious intervention.

But we do not always live under "normal" conditions. We have set up standards for both man and his animals which differ greatly from those to which they have been adapted, and we use as foods and feeding stuffs a great variety of artificial products with which it is possible to tax the adaptability of the animal quite beyond the limits of toleration.

Indeed we are each year becoming more and more independent of the environment to which, through long ages of selection, our physiological processes have come to be attuned.

This fact imposes upon us the obligation to seek an understanding of the physiology of nutrition in order that our increasing abilities to shape our own lives may not find us wanting in intelligence to use our capacities to the best possible advantage.

The practical bearing of this subject has to do with normal growth, especially of the bones of animals, and the prevention of malnutrition of the bones—a very common trouble in certain regions; with rickets and osteomalacia in both man and other animals; with osteoporosis in live stock; with “bran disease” or “miller’s horse rickets” and with the quality of the bones in horses; with acidosis in infants—a very common and troublesome nutritional disturbance and with diabetes and fevers.

It has a direct bearing on the production of all proteid increase in animals and hence upon the profitability of stock-farming, but especially on the rearing of those animals which are fed most largely upon cereals, especially corn alone, namely, swine and poultry. It has also a less important though an interesting bearing on the feeding of carnivorous animals in captivity, since they do not thrive on a diet of meat alone.

PHYSIOLOGICAL BASIS.

The main facts in physiology regarding the acid and alkaline mineral elements are as follows:

There are in all foodstuffs and in the living tissues of animals, mineral elements in organic combination, which upon oxidation in the body, yield inorganic acids. The animal must be protected from these acids, which would produce profound disturbance of function if allowed to circulate throughout the body. To this end they are neutralized with substances possessing a basic reaction and then, in their neutral condition, are either excreted or used as nutrients.

In this connection we consider especially the acid-reacting elements, sulphur, phosphorus and chlorine and the alkali-reacting elements, sodium, potassium, calcium and magnesium. Iron is not considered, since it is either base or acid according to circumstances and enters into vital activities only in its organic combinations.

THE ACID MINERAL ELEMENTS.

Sulphur enters the body almost wholly in organic combination as a constituent of food-proteins. As these proteins are oxidized in the body most of the sulphur is burned to sulphuric acid and is excreted in the urine as inorganic sulphates.

According to Sherman¹ 80 to 85 percent of the urinary sulphur in the human being is in the form, mostly of inorganic, but partly of ethereal sulphates, the remaining 15 to 20 percent being found in less completely oxidized forms. This latter portion is designated "neutral sulphur" and consists of derivatives of taurin from the bile, sulphocyanids from the saliva and a considerable number of other compounds, some known and others as yet not identified.

According to Neuberg and Grosser², in addition to the inorganic and ethereal sulphates and the neutral organic compounds of sulphur in the urine, there is also a basic fraction made up of salts of an organic sulphonium base.

In the body, sulphur is used as a constituent of all proteid increase and in the repair of proteid waste. A considerable part of the food-protein, however, is oxidized for the production of energy and its sulphur and phosphorus appear mostly as sulphates and phosphates, in the excreta. The constant waste which there is in the proteids of the living tissues, also contributes to the production of the sulphates and phosphates of the excreta.

Phosphorus enters the body in a great variety of conditions; as inorganic phosphates; as salts of various organic acids; as lecithins, that is, compounds of fat, phosphoric acid and a nitrogenous group; as phosphoproteins and as nucleoproteins.

The distribution of the phosphorus of the excretions between urine and feces is governed by the nature of the food.

In herbivora nearly all of the phosphorus is excreted in the feces. In carnivora almost all of the phosphorus is excreted in the urine; while in omnivora, man included, the distribution of the phosphorus between urine and feces, seems to depend largely on the calcium and magnesium contents of the ration. In man about two-thirds of the phosphorus usually leaves the body in the urine and about one-third in the feces, while an increase of the vegetables in the dietary and of the magnesium and calcium intake, will increase the proportion of the phosphorus leaving the body in combination with mineral bases, in the feces.

In the body, phosphorus serves a multiplicity of purposes, both structural and regulative, and is used both in organic and inorganic combinations.

The urinary phosphorus is chiefly in the form of di- and monohydrogen phosphates of sodium and potassium; less abundantly in the form of phosphates of calcium and magnesium. The phosphorus of the feces is also largely in the shape of phosphates. Phosphorus in various organic combinations also occurs in the feces, including nucleins and ether-soluble compounds.

Chlorine enters the body as chlorides and leaves it almost wholly in the urine, as chlorides. In the body it is used as chlorides and as hydrochloric acid in the gastric juice, principally for regulative and digestive purposes.

THE BASIC MINERAL ELEMENTS.

The mineral bases, calcium, magnesium, sodium and potassium, enter the body mostly as salts of various organic and inorganic acids; though calcium, at least in milk, egg-yolk and seeds, occurs also in organic combination with proteins.

These alkali-reacting elements are used in the body mostly in inorganic combination with phosphoric, sulphuric, hydrochloric and carbonic acids, principally for structural, regulative and catalytic purposes. They leave the body as inorganic salts in combination with the above-mentioned mineral acids.

Thus it is seen that these mineral elements, both acid and basic, enter the body in a great diversity of forms, both organic and inorganic, perform in the body a multiplicity of complicated functions and then leave the body mostly in an inorganic condition.

ACIDOSIS.

Causes. When oxidizable organic compounds, either nitrogenous or acid, containing sulphur or phosphorus, are disintegrated, or when chlorides are decomposed in the animal body, there are formed, from the sulphur, phosphorus and chlorine, the corresponding non-oxidizable inorganic acids. Since these acids cannot be broken up by oxidation and excreted by the lungs, they possess a different significance from oxidizable organic acids. An excess of these or other mineral acids, or of non-oxidizable organic acids, in the body, gives rise to a pathological condition known as acid intoxication or acidosis. Acidosis is a name first used by Naunyn¹⁶ to designate the excess of oxybutyric acid present in the blood in *diabetes mellitus*. It is, however, used to designate intoxication from other acids, either produced within the organism or introduced from without. In the use of this term the idea to be conveyed is that of an *excess* of acid. This may be brought about by the introduction or formation of abnormal amounts of acid, the bases not increasing in the same ratio, in which case the acidosis is said to be "absolute" (Naunyn), or it may be caused by a withdrawal from the body, of alkalis, the acids predominating merely because of this withdrawal of alkali, which type of acidosis was designated as "relative acidosis" by Steinitz.

The existence of acidosis is to be inferred from the excretion, by the kidneys, of an increased proportion of the nitrogen of the urine in the condition of ammonium salts, since ammonia is largely used by the animal to neutralize non-oxidizable acids.

In human pathology acidosis of the first type is most commonly caused by oxybutyric acid. In certain liver diseases lactic acid is also present in considerable quantities and uric, oxalic and aromatic acids may also contribute to its causation.

Diabetic coma or stupor is the result of acidosis, caused by a flooding of the tissues with oxybutyric acid and the related acetic acid. These acids are represented in the urine of healthy human beings by acetone, which may be formed from acetic acid by the splitting off of carbon dioxide.

Stadelman³ first proved that diabetic coma was caused by an increased formation of these acids and that they were excreted by the kidneys in combination with ammonia.

These acids are formed in the body from fats (Magnus-Levy¹⁷) and their formation is caused by lack of carbohydrate (Hirschfeld¹⁸) in the diet, or by derangement of the carbohydrate metabolism, as in diabetes.

Oxalic acid, which is difficultly oxidizable, may also contribute to the causation of acidosis in human beings. It is introduced into the body in foods of vegetable origin and is to some extent formed in the body itself.

Acidosis of the second, or relative type, is caused principally by the sulphuric and phosphoric acids normally produced in the body by the cleavage and oxidation of proteids, either of foods or tissues, containing sulphur and phosphorus as constituent parts.

The formation, from fatty acids and alkalis in the intestine, of soaps, which because either of difficult solubility or of digestive disturbance are passed off in the feces instead of being resorbed, is a prominent factor in the production of the second type, or relative acidosis, particularly in infants suffering from digestive disorders.

The essential cause of acidosis is a disturbance by acids, of the reaction of the blood. Henderson⁴ regards both blood and protoplasm to be characterized by "a very faint preponderance of alkalinity."

Neutrality of blood. The cause of this approximate neutrality is, according to Henderson, largely the result of a physico-chemical equilibrium between the carbonic acid, sodium bicarbonate, mono-sodium phosphate and di-sodium phosphate contained therein and maintained by secretory capacity of the lungs and kidneys.

Henderson explains the existence of this equilibrium as follows:

"In protoplasm phosphates are present in very great amount, undoubtedly as mixtures of mono- and di-potassium phosphates and similar salts; such mixtures constitute a nearly neutral solution which has the remarkable property of being able to take up large

quantities of acid or alkali without becoming acid or alkaline. This behavior is easily explained by the facts that acid sufficient to convert all the di-potassium phosphate of such a mixture into mono-potassium phosphate must be added before the slight acidity of mono-potassium phosphate is obtained, and that enough alkali to convert all the acid potassium phosphate into di-potassium phosphate must be added before the faint alkaline reaction of the latter substance is obtained, while, in accordance with the requirements of the concentration law, all mixtures of the two substances are much more nearly neutral than either alone."

Symptoms of acidosis. The symptoms of acute acidosis are "air hunger," rapidity of the pulse, depression, stupor and deep coma. These symptoms seem to result from diminished oxidation, due to an accumulation of carbon dioxide in the tissues. This is caused by the diminished alkalinity of the blood, which results in its inability to transport carbon dioxide to the lungs.

The most important effects of a deficiency of mineral bases or an excess of mineral acids in the body are not made apparent by the above-mentioned acute symptoms. Of vastly greater importance must be the less noticeable influence of slightly unbalanced rations upon the development and general health of animals, when these influences remain operative during long periods of time. Little that is definite is as yet known regarding these effects. We feel safe in assuming, however, since acute malnutrition of the bones may be so readily caused in a few weeks by irrational nutrition, that a slight departure from the optimum relationship of bases to acids in the food, if persisted in during the whole of the growing period, can not be without serious consequences in the development of the skeleton.

Indeed, it is a matter of common knowledge that prevailing methods of feeding of swine in the Corn Belt result in just such a gradual moulding of the style of growth as the animal develops, and this at least partially on account of the acid ash of corn.

After so much has been said about excess of mineral acid in the animal body, a fair question would be: "What about mineral bases? Would not an excess of alkali be equally dangerous?" So it might be, but the body has apparently an entirely adequate method of disposition of alkalis so that injurious excess does not occur. Volatile alkali (ammonia) is excreted in salts of mineral or organic acids, or as urea and fixed alkali (sodium and potassium) and alkaline earths (calcium and magnesium), as salts either of acids such as sulphuric, phosphoric, hydrochloric or carbonic acid, or of certain organic acids.

The neutralization of acids. A very slight disturbance by acids of the reaction of the blood must result in a complete disappearance from it of carbon dioxide. Thus it becomes a matter of much importance to the animal that the neutrality or slight alkalinity of the blood be abundantly safeguarded.

In herbivora this is accomplished by the formation of carbonates, in the body, by oxidation of the abundant organic-acid-salts of sodium, potassium, calcium and magnesium which are found in vegetable foods, and under ordinary circumstances the carbonates thus formed are quite sufficient to meet the requirements of the animal. In this class of animals there is but very slight provision for any other method of neutralization of acids.

Because of the practical inability of herbivora to neutralize acids with ammonia and the limited capacity of carnivora and omnivora to do the same, there comes a time, with increased consumption or production of non-oxidizable acids, and much more quickly with herbivora than with omnivora and carnivora, when the animal is no longer able to maintain the neutrality of its blood and tissues. At this point acute symptoms of acid intoxication, or acidosis, as it is called, appear and death may follow quickly with symptoms of asphyxia.

Omnivora and carnivora consume comparatively little mineral base in combination with organic acid and also comparatively little preformed carbonates. Further than this, their food, being much richer in protein than the food of the herbivora, produces correspondingly greater amounts of sulphuric and phosphoric acids by its cleavage and oxidation within the body. Hence we see that there is necessity for the provision of an extensive acid-neutralizing function in these animals. In accord with this requirement we find that carnivora and omnivora have the capacity to neutralize a certain amount of acid in the body with ammonia. This use of ammonia for acid-neutralization does not increase in extent proportionately with increase in the consumption of protein, however; otherwise there would be no such thing as acidosis from an exclusive protein diet, the fact of the existence of which is abundantly demonstrated.

This ammonia which is used for acid-neutralization has its origin in three distinct processes.

(1) Ammonia is produced in the digestive tract in considerable quantities, and by way of the portal vein and other channels reaches the other tissues of the body. It is also formed in all the organs of the body and by them is contributed, possibly as the carbamate, to the blood. According to Magnus-Levy⁶ the process of splitting off ammonia from protein is widely prevalent and generally, or often,

precedes the oxidation of the carbon-containing residue. Thus we may consider ammonia as a normal product of the disintegration of protein and its universal presence in the tissues as affording a slight store of alkali available for acid-neutralization.

(2) A second fraction may be considered to be split off from proteids especially for the purpose of acid-neutralization. Thus Folin⁸ says: "In the study of ammonia as a product of metabolism,* it must be remembered that this substance is a base, and its formation in the animal organism is therefore probably quantitatively determined by the necessity of forming salts." Magnus-Levy⁷ with the same idea in mind says: "As soon as the amount of acid produced exceeds the amount necessary to neutralize the stored-up ammonia or other alkali, autolysis† sets in, and nitrogenous equilibrium ceases to be maintained."

"In well nourished animals there is always an excess of ammonia present which gradually disappears as the animal is deprived of food. A certain stage will then be reached when the production of acid exceeds the amount of ammonia available for neutralization; the autolytic enzyme then comes into play, liberates amino-acids, etc., which in their turn pass to the alimentary tract, and by means of the metabolic processes taking place then liberate ammonia, which again inhibits the production of nitrogenous degradation products." This second fraction then, may be considered to represent a purposive adjustment.

(3) The third source of ammonia available for acid-neutralization is of much greater importance, quantitatively, than the two above-mentioned. This fraction becomes available through its withdrawal from urea formation in the liver.

In mammals, very much the greater part, about 80 percent, of the nitrogen leaving the body, reaches the kidneys as urea. It is formed chiefly in the liver, though also to slight extent in other organs, and chiefly by synthesis, or constructive reaction, from ammonium compounds, possibly from the carbamate or the carbonate, though probably also formed to some extent (Drechsel⁹) directly from certain proteids by a simple splitting or cleavage of the compound, with the taking up of water, and thus without synthesis or constructive change.

* Metabolism is chemical change due to the processes of life.

† Autolysis is that type of chemical change from complex to simpler compounds which is exemplified in the ripening of beef and cheese. Such changes are produced through the agency of a group of chemical compounds which are universally present in plant and animal tissues and which are known as enzymes.

This formation of urea in the liver, from ammonium compounds, may be spoken of as for the purpose of affording the body protection from ammonia. Thus we may consider that the ammonia in the body, available for purposes of acid-neutralization, comes (1) from the tissues, (2) from body proteids and (3) by withdrawal from urea formation.

The nitrogen of the urine may be caused to appear therein almost wholly as ammonium salts by the administration of mineral acids. Conversely the nitrogen of the urine may, by the administration of alkali carbonates, be caused to appear in the form of urea, with a great reduction in the amount of ammonium salts present.

Walther¹⁰ first proved, with dogs, that after administering hydrochloric acid, there was a marked increase in the ammonium salts of the urine, about three-fourths of the hydrochloric acid being excreted in this form.

Organic acids, in general, cause no increase in the excretion of nitrogen as ammonium salts since they are, as a rule, oxidized to carbon dioxide and water and are excreted in these compounds; benzoic and certain related acids, however, are not oxidized, and oxybutyric, acetic and lactic acids may be, like the mineral acids, excreted in combination with ammonia.

Now, have we right to consider that neutralization of acids by ammonia affords the animal as complete protection as their neutralization by fixed alkalis or alkaline earths?

Voegtlin and King¹¹ suggest that the ammonium salts themselves may play "an important role in producing the symptoms of these diseases." Intravenous injections of ammonium salts of lactic, hydrochloric and beta-oxybutyric acids produced symptoms of acid intoxication, while intravenous injections of calcium salts completely antagonized the toxic action of the ammonium salts.

According to A. P. Mathews⁵⁰ ammonium salts in solution decompose, not only into the ammonium and acid groups but also, to a certain extent, with the taking up of water, into ammonium hydroxide and the free acid. These decompositions may subject the animal to the action of ammonia, as stated by Mathews, and of the acid involved, as implied by Voegtlin and King. Thus we may consider it at least a possibility that neutralization of acids by ammonia does not afford an animal complete protection from these acids.

A second source of acid-neutralizing material in all animals is the calcium salts of the bones and other tissues. Where a ration characterized by a deficiency of mineral bases is fed during a considerable period of time, as for instance, in feeding corn to swine,

(see experiments by the author¹²), the withdrawal of mineral matter from the bones and the prevention of its deposit within them, may affect not only the size and strength of the bones, but the size and general style of development of the animal.

That the calcium of the blood may also be used for acid-neutralization is indicated by the fact of the great variability of the content of blood in this element. According to Albu and Neuberg¹³, Bunge found .04 percent of calcium, reckoned as the oxide, while Demstedt and Rumpf found values up to .27 percent. That the calcium content of the blood depends upon the food was proven by Hirschler and Terray who found it varying between .0023-.0051 percent (CaO) in accordance with the food.

Rey¹⁹ also has demonstrated with dogs a very considerable retention of calcium in the blood for some days and Weiske in his experiments with rabbits has, by feeding calcium carbonate with oats, shown an apparent increase in the calcium carbonate in the ash of the bones from 5.5 and 6.2 percent to 7.6 and 8.4 percent.

According to Albu and Neuberg¹⁵, Rüdell found with dogs, after the administration of hydrochloric acid, an increase to twice the quantity, and Gäthjens, after the administration of sulphuric acid, three times the quantity of calcium in the urine; and Caspari, after giving oxalic acid, as much as ten times the normal average. Rumpf saw an increase of 50 percent in the calcium excretion in men, after the administration of lactic acid and sodium lactate.

O. Wellmann²⁰ found that the calcium and phosphorus excreted from the body during fasting comes from bone substance and S. W. Patterson²¹, in experiments with rabbits fed on oat-meal and corn-meal, that the deficiency of these foods in calcium results in a loss of calcium from the bones.

Thus in considering this matter of balance between mineral acid and mineral base in animal nutrition, we must think of the acids as produced (1) by the destruction or katabolism of the body proteids, (2) by the oxidation of food proteids, and (3) to a slight extent by the decomposition of sodium chloride in the formation of gastric juice.

On the other hand we must consider the bases available for their neutralization as contributed principally (1) by the carbonates formed from alkali salts of organic acids in the food, (2) by the withdrawal of ammonia from the formation of urea in the liver, (3) by ammonia split off from body proteids, for the purpose of acid-neutralization, (4) by carbonates and ammonia of the tissues and (5) by the decomposition of sodium chloride in the formation of gastric juice.

Effects of acidosis. The first substantial progress toward an understanding of acidosis was due to the studies of Forster, Bunge and Lunin.

Forster²² fed dogs and pigeons on practically ash-free food. They succumbed in a very few days. He considered the lack of mineral matter to be the cause of death.

Bunge²³ however, suggested that the fatal termination of the experiment might be due to sulphuric acid produced by the oxidation of protein.

Lunin²⁴ put this idea to a test by feeding mice on an ash-free diet, with and without sodium carbonate. With the sodium carbonate the mice lived twice as long as without it, because this salt neutralized the acids produced by the oxidation of proteids.

Kemmerich²⁵ found it impossible to maintain young dogs on meat-scrap from which the minerals had been extracted.

Salkowski²⁶ and Walter²⁷ found that the administration of hydrochloric acid to rabbits and dogs resulted in a withdrawal from their bodies of the fixed alkalis, and in death.

Salkowski first learned that acids produced in destructive or katabolic processes of human beings, of carnivora and of herbivora may be excreted united with mineral bases.

Effects of diet of meat. Chalmers Watson²⁸ has found that in animals fed on an exclusive meat diet the bones present an appearance of delayed and imperfect ossification with increased vascularity, or blood content, and an increase in the number of red blood-corpuscles. The symptoms are very similar to those in rickets in human beings, but microscopic examination shows that they are not identical.

D. Forysth²⁹ however, fed domestic fowls for periods varying from 11 months to 2 years upon meat, supplemented by lime. The animals remained healthy and their bones normal.

E. J. Spriggs³⁰ found that rats when fed on meat alone had rough and abnormal coats, but that when lime was added to the diet the appearance of the coat was nearly normal.

Effects of diet of cereals. Weiske³¹ found that exclusive oat feeding to young rabbits resulted in a very marked demineralization of the skeleton generally, but not of the teeth. His observations regarding the teeth are, he says, in accord with those of H. Beraz (Zeitschr. f. Biol. Vol. 17, p. 386.)

While the dry, fat-free weight of the skeleton decreased, that of the teeth increased during the feeding of oats, with calcium sulphate in one case and tricalcic phosphate in another.

It is of interest to note that the administration of calcium phosphate with the oats did not prevent a loss in the dry, fat-free weight of the skeleton.

Weiske has also shown, by administering dilute sulphuric acid or monosodium phosphate in the food, to rabbits and sheep, that the percentage of ash in the bones could be decreased. By continuous feeding of cereals, for protracted periods, to mature herbivora, he also produced demineralization of the skeleton.

In unpublished experiments by the author, with swine, in the comparison of the nutritive values of various compounds of phosphorus, malnutrition of the bones has been caused by insufficiency of mineral bases to neutralize the mineral acids present. A low-phosphorus basal ration, supplemented with hypophosphites, produced acute disturbance of nutrition, as shown by great lameness, stupor, excessive fatness, minimum increase in weight of muscles, maximum percentage of fat in the increase, decided loss in breaking strength and in ash per cubic centimeter and in total weight of ash of the bones. This ration produced knob-like swellings at the point of union between the ribs and their cartilaginous extensions and required modification in order to keep the pigs alive for fifty-six days.

The same basal ration, supplemented by glycerophosphates of the same mineral bases, produced great increase in the size, breaking strength and total ash in the bones and also in the ash per cubic centimeter of bones. There was also a maximum increase in the weight of the muscles and a minimum percentage of fat in the increased weight, and the pigs thrived exceedingly. These differences, in so far as they relate to the bones, are due largely to the greater proportion of acid to base in hypophosphites than in glycerophosphates; and as they relate to muscular development, are due to the fact that glycerophosphates are useful in muscular growth, while hypophosphites will not sustain development of these tissues.

In earlier work the author found that water-extract of wheat bran, which contains an abundance of phosphorus as calcium-magnesium-potassium-phytate, had the capacity greatly to strengthen the bones of pigs and to contribute to the growth both of bones and muscles, but when this food was used in excess it caused, probably through an excess of acid mineral elements contributed to the ration, pathological symptoms and much less increase in the growth of bone and muscle.

"Bran disease," "shorts disease" or "miller's horse rickets" is in all probability malnutrition of the bones, possibly combined with acidosis, due to lack of calcium in the food, and perhaps to a superabundance of acid mineral elements; possibly also to an excess of magnesium.

It is very well known by all intelligent swine-breeders that corn alone does not produce maximum growth of bone. The fact has also been proven, many times over, by a large number of experimenters in the field of animal husbandry, especially by Henry, of Wisconsin, and by thousands of stock-raisers in every-day practice, that the addition of mineral matter, either in other foods or by itself as in wood-ashes or bone-meal, is beneficial to bone formation and also, to some extent, to structural development generally.

This deficiency of corn in mineral matter is due to a lack of mineral bases generally and to lack of calcium especially, and probably also to a lack of phosphorus. It is possible that unfavorable effects are also due to an excessive proportion of magnesium in relation to calcium. In bone there is 86 times as much calcium as magnesium and in the body generally about 40 times as much, while in corn there is ten times as much magnesium as calcium. Certain evidence lends support to the idea that this disproportion of calcium to magnesium in corn may be a matter of importance. In our experiments corn alone has produced weak bone and little muscle, while the addition of protein and mineral matter, in the shape either of organic or inorganic phosphates, has proven quite effective to cause increased capacity to produce bone and muscles. Feeding on corn alone often results in the "breaking down" of fat hogs on the way to market and of brood sows upon the farm. Show hogs often exhibit symptoms of a similar weakening of the tendinous attachments when "let down" too rapidly after the show season and hogs being fitted for show are often "fed off their feet," as the saying goes, by crowding them along too fast on foods which contain a deficiency of mineral bases (especially calcium) in relation to the acid mineral elements present.

MALNUTRITION OF THE BONES.

These above cases of malnutrition of the bones are the results of two factors, (1) lack of bone-forming constituents and (2) an excess, either absolute or relative to mineral bases, of acid mineral elements.

These same factors receive consideration as contributory causes of osteomalacia, rickets and osteoporosis, diseases in which malnutrition of the bones is a prominent symptom, though malnutrition is by no means the sole cause of these difficulties.

Rickets and osteomalacia are diseases involving various tissues; among others, the bones. In rickets demineralization occurs through a loss of capacity, by the bone-forming tissue, of the power of absorbing and assimilating calcium. In osteomalacia there is a loss of the power of the bones to retain calcium. The cause of

neither disease, as it occurs in human beings, is known. While these diseases often follow deficiency of the food in calcium and phosphorus, this is by no means the only cause and in human beings, at least, apparently not the fundamental one, especially in rickets.

Osteomalacia. In osteomalacia it appears that the carbonates are not removed from bone more rapidly than the phosphates.

Magnus-Levy³² found in the bones of a woman who had died from osteomalacia that the calcium and phosphorus decreased in the same ratio, one to another, as that in which they occur in normal bone. In treating fresh, normal bone with lactic acid, much more of the carbonate dissolves out than of the phosphate.

Mohr³³ says regarding metabolism in osteomalacia, "It is an important fact that the loss of mineral matter affects all the constituent elements equally and not the calcium especially."

Thus it is apparent that the loss of mineral matter from the bones in osteomalacia is directly due to autolysis and not to solution in free acids.

Veterinary writers usually say without qualification that osteomalacia is caused by lack of mineral salts in the food. Thus Atkinson and Mohler³⁵ say, "The cause of this affection is the insufficiency or total absence of lime salts in the food, also to feeding hay of low, damp pastures, kitchen slops and potatoes, or to overstocking lands. It occurs on old, worn-out soil, devoid of lime salts, and has been observed to follow a dry season. The disease in this country is confined to localized areas in the Southwest, known as the "alkali districts," and to the old dairy sections of New York."

In the 15th Annual Report of the Bureau of Animal Industry, 1898, p. 530, osteomalacia is reported as common in Texas, especially in dry summers. The cause is here stated to be an insufficient supply of certain mineral ingredients in the food, probably phosphates of lime.

Law³⁶ speaks of the prevalence of the disease in damp lowlands of Belgium and Jutland, in the Swiss valleys, on the damp lands of New Jersey and the Carolina seaboard, and generally on damp pastures with rank, watery herbage.

A large number of agriculturists and veterinarians, in Europe and in South Africa, also believe that the cause of osteomalacia is a deficiency of the herbage in calcium and phosphorus, either because of natural poverty of the soils in these elements, as in parts of South Africa, and in certain regions in the Hawaiian Islands, or because of abnormally low calcium and phosphorus contents of the forage on worn lands, following a dry season.

The above ideas as to causes of osteomalacia in live-stock are easily harmonized.

In dry seasons the minerals in the forage are deficient because of diminished transpiration of water. In dry regions we have the same condition present. Scanty food, due either to drought or to over-stocking of the pasture, also limits the amount of mineral nutrients available to the animal. On soils naturally deficient in lime or phosphorus, or on those depleted by tillage, the forage is low in these elements. On abnormally damp pastures or poor lands a low mineral intake might be explained simply by the bulky character of the watery grass. Then too its laxative character would interfere with the utilization of its nutrient constituents. The author has seen chinch bugs thrive exceedingly in an insectary on scantily watered corn, while they drank themselves to death on the dilute sap of generously watered plants. Animals most likely to suffer from osteomalacia are colts, cows with the first calf and heavily producing milk cows.

The symptoms, according to Atkinson and Mohler³⁵, are "a gradual emaciation and symptoms of gastro-intestinal catarrh, with depraved appetite, the animal eating manure, decayed wood, dirt, leather, etc. Muscular weakness is prominent, together with muscle tremors, which simulate chills, but are not accompanied by any rise of temperature. The animal has a stiff, laborious gait; there is pain and swelling of the joints, and constant shifting of the weight from one leg to another. The restricted movements of the joints are frequently accompanied by a crackling sound, which has caused the name of "creeps" to be applied to the disease. The coat is dull and rough and the skin dry and hidebound. The animal is subject to frequent sprains or fracture of bones without apparent cause, as in lying down or turning around, and when such fractures occur they are difficult to unite. The bones principally involved are the upper bones of the legs, the haunch bone, and the middle bones of the spinal column."

Friedberger and Fröhner³⁷ consider that, in live stock, there is a close relationship between osteomalacia and rickets and speak of rachitis as "a form of osteomalacia due to special conditions of growth of the young bone."

They consider an insufficient quantity of calcium in the food, either from deficiency of the soil in calcium, or from climatic influence, to be a cause of this disease.

Bran disease of horses they describe as but a form of rickets and also say that in old animals it is identical with osteomalacia.

In this disease there are bony enlargements about the articulations of the knees and tarsus and changes appear in the bones of the head, including loss of the teeth. The disease may result fatally.

Friedberger and Fröhner speak of rickets as being especially common in young pigs and dogs and state that its dominating cause is want of calcareous salts in the food.

Prominent among the anatomical symptoms are congestion and thickening of the periosteum; the bone becomes covered with exostoses, especially at points of muscular attachment; muscular contractions may remove the thickened periosteum; profound changes also occur at the ends of the long bones which result in abnormal growth of the cartilage and in various deformities. In live-stock this disease responds readily to treatment with calcium phosphate, which may be supplied mixed with salt. A change of ration to one containing an abundance of calcium is also of decided benefit.

Osteoporosis. This disease appears to be distinct from osteomalacia. Its cause is unknown. It does not respond to medication with calcium phosphate and is not caused by deficiency of the food in calcium and phosphorus, though this may be a contributory cause.

Mohler³⁸ says of this disease: "In the southwest, where osteomalacia or "creeps" has not infrequently been observed by the writer among range cattle, no case of osteoporosis of the horses using the same range has been noted, although the latter are given no more care or attention than the cattle."

"Osteoporosis is a general disease of the bones which develops slowly and progressively and is characterized by the absorption of the calcareous or compact bony substance and the formation of enlarged, softened and porous bone. This fragile and deformed condition is particularly manifest in the bones of the head, causing enlargement and bulging of the face and jaws, thereby giving rise to the terms "big head" and "swelled-head" which are applied to it. The disease affects horses, mules and asses of all ages, classes, breeds, and of both sexes, but is probably more frequently observed in mature horses and Shetland ponies. The disease is found under all soil, food and climatic conditions."

The terms "osteoporosis" and "big-head" have also been used by A. W. Bitting³⁹, of the Florida Station, to apply to the same disease.

There is some confusion in literature regarding the application of the term "osteoporosis" for Mohr³⁴ uses it to apply to experimentally produced fragility of the bones caused by the administration of lactic acid or of foods containing no lime.

Hammarsten¹⁰ referring to the experiments of E. Voit uses the term "osteoporosis" to apply to rachitic changes in bones of young animals, caused by lack of calcium salts in the food.

In this country we use "osteoporosis" to signify a definite disease, especially of horses, which is not caused by a lack of lime salts in the food. This use of the term is also so general elsewhere among veterinarians, that it should be restricted in its application to this communicable disease.

H. Ingle,⁴¹ writing from Transvaal, reports analyses of the bones of horses, mules and asses which had suffered from osteoporosis. He found the ratio of nitrogen to ash to be 1:10.8 in bones of animals which had suffered from this disease and 1:14.37 in sound bones. The relation of phosphorus to calcium was the same in both cases.

Ingle considers that the cause of the disease is the low proportion of calcium to phosphorus in the oat-hay and Indian corn which compose the usual ration for these animals in Transvaal.

From Laws and Gilbert's analyses he concludes that the amounts of lime and phosphorus pentoxide in the ash of foods should be about equal. In the ash of South African oat-hay he finds the proportion of phosphorus pentoxide to lime to be as 100:51 and he quotes Wolff's analyses showing the proportion of phosphorus pentoxide to lime to be in Indian corn as 100:4.

Ingle also notes the fact that the ash of wheat bran contains phosphorus pentoxide and lime in proportion of 100:9 and considers its poverty in lime to be the cause of "bran rachitis," "bran disease" or "miller's horse rickets." The evidence, however, does not sustain Ingle's belief that deficiency of the forage in calcium is the primary cause of osteoporosis.

D. Hutcheon, Chief Veterinary Surgeon in Cape of Good Hope, whose abundant experience with osteomalacia in South Africa leaves him with the conviction that this disease is caused by deficiency of the food in bone-forming constituents, and who has found that it responds readily to medication with salts of calcium and phosphorus, insists that the osteoporosis of horses is an entirely distinct malady and that it is not caused primarily by deficiency of the food in calcium salts; further, he finds that it does not respond to treatment with bone-meal as does osteomalacia. It is apparently a communicable disease though the method and cause of infection are unknown.

Hutcheon distinguishes between the effects of these diseases upon the bones in part as follows:

"In osteomalacia the diseased bones retain their normal size and external appearance, but there is a softening of the walls of the bones, with slight enlargement of the medullary spaces, the marrow in which becomes highly vascular, and an increase in the cancellous tissue toward the ends of the long bones."

"In osteoporosis the affected bones are enlarged, their tissues soft and elastic and their honeycomb structure full of extravasated blood. The osseous tissue is pink, soft, easily cut with a knife, is spongy, elastic and yields blood upon pressure. The Haversian canals are greatly enlarged and filled with gelatinous exudate."

The most that can be said relative to remedial treatment is that a change of conditions and surroundings often affects a cure even in cases that have become severe.

THE HUMAN DIETARY.

This subject is of importance in human nutrition because of its bearing upon the matter of diet in diseased conditions and because of possible cumulative effects upon the development of the tissues through slightly abnormal conditions long sustained.

This generation of Americans, at least, feed themselves a superabundance of protein, especially in the form of meat. Meat does not contain enough mineral base to neutralize the mineral acids which may be produced from it in the body.

Vegetables and fruits are, because of their great excess of basic over acid mineral elements, much better suited to supplement meat than are the cereal preparations, none of which have any considerable preponderance of mineral base, while in most, the balance is in favor of mineral acid.

White bread has an excess of acid minerals and so have corn and most of our multitudinous, prepared breakfast foods.

This overconsumption of protein, especially in meat, coupled with our increasing use of cereal preparations and of sugar, which supplies carbohydrates without basic mineral matter, requires of us that we give attention to those foods which are by nature fitted to supplement this one-sided ration. Such foods are vegetables, especially, and also fruits.

We do not have definite evidence upon the strength of which to assert that a failure to consider this matter has led to the development of weak bones and poor teeth in human beings, but since the skeletons of other animals may be ruined by a very few weeks' feeding of these animals on meat alone or cereals alone, we must in fairness to ourselves consider it at least a possibility that wrong habits in the choice of food, especially for children, may in the course of the growing period unfavorably influence the development of the bones.

The liking for vegetables often requires to be cultivated in a child and not all children care for milk. Two such have come to the author's notice. Fortunately they are fond of fruit. Without fruit or vegetables or milk it would be difficult to satisfy a child with foods which provide a sufficient excess of mineral base over mineral acid, to insure the maximum growth of healthy bones.

It is easier and more comfortable to trust to instinct in these matters, but with our increasing independence in the choice of food, we must accept the burden imposed by our prosperity and learn rationally to shape our ways. Our interest in these matters is exactly similar to that of the traveller by foot who after having taken to an automobile, comes to have a new concern as to whether it is a field or a declivity over the hedge at the next turn of the road.

Where so many of the ills to which the flesh is heir are due to, or are influenced by, derangements of nutrition it seems that knowledge in this field should be a part of whatever system of living or education one may choose to follow.

Acidosis in infants. In infant feeding, acidosis is an exceedingly common source of trouble. The difficulty is most frequently met with in artificially fed infants.

Cow's milk supplies to the infant a greater amount of digestible protein in proportion to available alkali than human milk and hence the acids formed by oxidation of this protein will be greater in amount, relative to alkali available for their neutralization. This calls for ammonia to make good the deficiency.

Another factor in the causation of infantile acidosis is the high fat-content of cow's milk. Steinitz showed that the increased excretion of ammonium salts, on a milk diet rich in fat, was a consequence of the removal of alkali by way of the intestine. A part of the calcium, which normally would be excreted as calcium phosphate, forms a difficultly soluble calcium soap with fats of the food, and is then excreted in the feces. Either excess or indigestible character of the fat in the food may cause this increased elimination of alkalis in the feces, which, together with the consequent increased ammonia excretion by the kidneys, constitute the two most prominent indications of acidosis.

The use of skim milk, butter-milk, barley gruel, orange juice and egg albumen tend to alleviate symptoms of acidosis by virtue either of low fat-content or predominance of basic over acid mineral elements.

The limited capacity of young animals to tolerate fat in the food is a matter of common observation among stockmen. Cattle raisers commonly believe that calves thrive better on Shorthorn or Holstein

milk than upon richer Jersey milk, and successful showmen commonly use as nurse cows, individuals of the breeds which yield milk relatively low in fat.

As bearing upon the feeding of infants we would call attention to the fact that selection has increased the fat-content of the Jersey cow's milk until even her own calf will thrive better on the milk of some other breed which yields milk that is not so rich in fat.

The writer once saw a thousand-pound Shorthorn steer calf which was being fitted for show, put onto a Jersey nurse cow which produced two pounds of butter-fat per day. For months the steer was a light eater and the slightest irregularity or change of food would throw him "off-feed." After the discontinuance of the services of his butter-producing foster-mother, he thrived exceedingly. It is possible that acidosis is caused by such an excess of fat through its combination and excretion with calcium in the intestines.

Czerny and Steinitz⁴³ note that Keller in studying children suffering with gastro-intestinal complaints found in the urine almost invariably an abnormally high ammonia excretion, amounting to 52 percent of the total nitrogen, and that Van der Bergh gave sodium bicarbonate to infants suffering from digestive disturbances with the result that the ammonia excretion immediately decreased in a very marked manner.

Czerny and Steinitz conclude that this increased ammonia excretion in the urine of children suffering with digestive disturbances indicates the presence of acids and is formed for the purpose of their neutralization and not because of defective urea synthesis by the liver.

Czerny and Keller find that, among the various foodstuffs, fat alone leads to an increased excretion of ammonium salts in the urine.

Keller⁴⁴ finds that free acids are not excreted in the urine of children suffering with gastro-intestinal disorders but that they are eliminated in combination with ammonia.

Steinitz concluded that a diet of milk which was rich in fat might exercise an unfavorable influence upon the growth of children suffering from gastro-intestinal troubles through causing a loss of alkalis, which are essential to normal development.

Acidosis may also be caused in infants by too strict an adherence to a cereal diet. Steinitz and Weigert⁴⁵ report the composition of the body of a four-months-old child which died as a result of an exclusively cereal diet. The composition shows the body to have lost a large part of the sodium, potassium and chlorine normally present.

Czerny and Steinitz say, "The importance of relative acidosis in chronic disturbances of nutrition in infants lies in the loss of alkali.

For the growth and health of the child's organism the retention of alkali is as important as the retention of nitrogen, phosphorus, or other mineral substances. If it is withheld, or a loss takes place, the condition of the body can neither improve nor remain normal."

MINERAL BASES AND ACIDS IN FOODS.

For the sake of convenience in this discussion we use the term "ash" to signify a combustion residue in which all of the acid-producing mineral elements of the fresh substance are present. Unfortunately we have not access to any considerable number of analyses of foodstuffs which accurately indicate the amounts of the mineral elements contained, since almost all of the available determinations have been made upon the ash, which does not contain all or nearly all of the mineral matter of the fresh substance.

Sulphur especially is largely lost during ashing, even if this is carefully done. Other elements may also volatilize in this process. The loss is much more likely to decrease the total mineral acid present than the total mineral base and the loss is greatest in those products where mineral acids predominate.

Hence in order that the following figures may not mislead it is necessary to consider them as but most general indications of the truth, except where we know that adequate means were used for the estimation of the total amounts of the minerals present in the fresh substances.

The errors are quite misleading in the case of the cereals and cereal by-products. The excuse which we have to offer for using these analyses for a purpose which they serve so imperfectly is that they are the best available at this time; they do indicate some general truths of importance and their use for this purpose should serve to call the attention of other workers in the same field to the great desirability of making accurate mineral analyses of our foodstuffs. The amount of labor involved in such work is very considerable but we shall be able eventually to substitute more accurate figures for these which we have compiled.

In order to indicate what the loss in acid mineral elements in ashing may signify, let us examine the figures for gluten flour, No. 31 in the table on page 44.

In this foodstuff, Mr. A. C. Whittier of this laboratory, found 8.39 parts of ash per 1000 parts of dry substance, by an approved method involving the leaching of the charred substance. Sulphur was determined by fusion with sodium carbonate and sodium peroxide over an alcohol lamp and the amount of sulphur found was 10 parts per 1000; a greater quantity than was found of all the mineral elements together, in the ash.

	Moist-ure	Ash	Potas-sium	Sodium	Calcium	Mag-nesium	Phos-phorus	Sulphur	Chlorine	C. C. Normal Solution, 1000 Grams				Authority for Analysis
										Total Base	Total Acid	Excess Base	Excess Acid	
1	Cow's milk	56.7	11.60	3.44	9.09	.88	6.50	.57	7.91	971.14	678.0	283.1	.....	K. II, 603
2	Woman's milk	24.2	6.79	1.65	2.88	.31	2.40	.18	4.45	414.11	291.6	122.5	.....	K. II, 598
3	Sow's milk	68.6	3.53	3.42	19.23	.74	11.13	.36	4.40	1258.40	921.1	337.3	.....	K. II, 602
4	Ewe's milk	69.0	13.95	2.30	15.34	.59	9.10	7.03	5.24	1259.6	759.2	510.4	.....	K. II, 602
5	Black Albumen	35.7	2.38	11.67	74.6	.17	7.95	.....	12.32	724.6	847.4	.....	122.8	Whittier
6	Beef	.....	15.12	2.69	758.0	.99	7.02	3.10	2.36	588.2	712.9	.....	124.7	Katz
7	Pork	.....	9.37	5.76	684.0	1.03	7.86	3.02	1.77	588.8	745.4	.....	156.7	Katz
8	Chicken	.....	14.72	3.00	684.0	1.17	8.01	3.70	1.90	619.7	801.2	.....	181.5	Katz
9	Eggs	34.8	5.55	4.53	2.10	.51	5.78	.13	4.85	484.9	517.8	.....	32.9	W. I, 158
10	White of egg	46.1	18.90	10.80	.92	.77	.89	.....	13.29	884.7	456.6	.....	428.0	W. I, 158
11	Potatoes	37.9	18.90	8.83	7.72	1.13	2.79	.99	1.31	647.5	278.7	368.8	.....	W. I, 158
12	Sweet Potatoes	50.7	12.82	2.49	2.18	.63	1.42	.68	3.91	552.6	244.3	308.2	.....	K. II, 898
13	Beets, red	59.7	8.44	21.60	2.49	.11	2.56	5.50	2.94	1295.9	279.3	1006.6	.....	K. II, 902
14	Turnips	80.1	30.20	5.85	6.07	1.79	4.45	3.59	4.06	1474.9	625.6	849.3	.....	W. I, 182
15	Tomatoes	260.5	82.50	22.93	11.36	13.57	10.73	4.98	18.05	521.6	1312.1	3704.5	.....	W. I, 156
16	Onions	52.8	10.98	1.25	11.36	1.68	3.46	1.16	1.46	886.1	336.8	549.3	.....	A. & N., 236
17	Cabbage, heart	108.5	25.10	8.05	16.63	2.34	7.11	3.72	8.53	201.9	931.4	1080.5	.....	K. II, 919
18	Asparagus	93.0	14.49	9.21	5.63	1.89	5.89	1.79	120.6	613.3	592.4	.....	.....	M. & Von L., 1905
19	Spinach	164.8	22.67	43.18	13.98	7.38	9.28	4.53	10.37	3570.2	1051.3	2618.9	.....	K. II, 924
20	Rhubarb	144.4	71.45	5.52	10.37	6.34	9.28	1.10	7.75	2581.7	886.0	1695.8	.....	K. II, 929
21	Oranges	30.8	9.31	3.08	5.40	1.50	1.49	1.46	7.72	763.9	145.1	618.8	.....	W. I, 128
22	Apples	14.4	4.27	2.79	.42	.76	.85	.35	.07	313.5	76.7	236.8	.....	W. I, 124
23	Plums	20.8	11.98	.36	.60	.61	1.19	.20	.07	401.6	91.2	310.4	.....	K. II, 959
24	Raisins	28.6	11.05	1.57	2.23	.98	2.23	.69	1.39	585.2	226.9	358.3	.....	A. & N., 237
25	Figs	29.2	13.54	.52	2.27	.99	1.63	.46	.60	562.9	150.8	412.1	.....	K. II, 959
26	Apricots	42.1	21.95	3.35	.89	.79	2.03	.43	.18	815.3	162.9	652.4	.....	K. II, 959
27	Wheat, grain	20.8	5.04	.26	.41	1.41	4.08	.09	.58	276.2	283.3	.....	9.1	M. & Von L., 1905
28	Wheat bran	61.6	14.58	.30	1.27	6.22	13.54	.02	6.53	959.4	874.9	84.6	.....	W. I, 126
29	White bread	21.5	1.25	3.14	.....	.29	1.58	.....	192.0	192.0	364.1	.....	172.2	A. & N., 227
30	Graham bread	26.6	3.21	2.86	1.03	.75	2.48	.22	6.41	319.0	354.1	.....	26.5	A. & N., 229
31	Gluten flour	8.4	.47	.43	.90	.59	1.96	10.00	.38	123.6	200.0	.....	78.8	Whittier
32	Rice, hulled	3.9	3.61	.16	.58	.26	.91	.01	.004	150.7	59.4	.....	9.8	Whittier
33	Oat meal	18.3	7.07	.97	.97	.86	3.85	.98	.98	236.4	279.2	.....	42.8	K. II, 834
34	Oats, grain	32.0	4.65	.35	.84	.34	3.77	.23	.35	285.9	267.0	18.4	.....	M. & Von L., 1905
35	Corn, grain	14.5	3.59	.12	.23	1.36	2.89	.13	.13	210.8	192.0	26.9	.....	Whittier
36	Corn, grain	15.5	3.20	.52	.11	1.25	3.36	1.66	.45	212.3	329.3	.....	117.0	K. II, 775
37	Corn bran	13.3	2.60	.00	.33	1.82	1.24	.16	.42	150.3	139.3	.....	.....	Whittier
38	pearl hominy	111.8	1.08	.12	.05	.40	.55	.36	.54	150.3	135.6	.....	83.4	.....
39	Beans	36.3	12.50	.29	1.30	1.57	6.16	.39	.08	523.6	446.3	79.3	.....	K. II, 784
40	Soy beans	31.4	11.62	.23	1.19	1.69	5.06	.39	.08	904.9	349.9	135.0	.....	W. I, 31
41	Cottonseed meal	74.8	18.48	.....	2.36	6.86	15.01	.37	.03	1133.9	992.3	160.6	.....	W. I, 127
42	Linsed oilmeal	58.4	11.82	.68	3.50	5.51	1.84	.78	.46	963.3	581.6	381.7	.....	M. & Von L., 1905
43	Corn stover	53.3	16.02	.44	4.15	1.85	1.61	1.13	.36	787.2	196.4	590.8	.....	.....
44	Oat straw	70.8	13.57	1.73	3.59	1.62	3.51	.93	4.67	849.2	258.4	445.5	.....	.....
45	Timothy hay	68.3	19.67	.95	3.92	1.34	3.51	.79	3.50	1736.9	316.5	1420.4	.....	.....
46	Red clover hay	68.6	18.38	.97	17.11	4.53	2.89	.90	2.62	1713.7	409.4	1304.2	.....	.....
47	Alfalfa hay	73.8	16.41	.97	21.44	2.23	3.88	1.72	2.98	1713.7	409.4	1304.2	.....	.....
48	Rape, green	80.8	22.35	2.29	12.64	1.86	4.03	4.62	6.15	1453.4	721.7	731.7	.....	.....

NOTE: The above analyses represent edible portions only.

The analysis of corn, No. 35, from König, is as satisfactory as any we were able to find in literature. A comparison of these figures with those of A. C. Whittier for the same product, No. 36, gives further illustration of the loss of minerals in ashing.

Thus it is apparent that final judgment as to the balance between basic and acid mineral elements in cereals must be withheld until warranted by further analytical work.

The analyses in the table on page 44, followed by the initial "K" are from König's "Chemie der menschlichen Nahrungs-und Genussmittel;" those ascribed to Katz are from Arch. ges. Physiol., vol. 3, p. 14; those followed by the initial "W" are from Wolff's "Aschen Analysen," "A. & N." signifies Albu and Neuberg's "Mineralstoffwechsel," "M. & Von L.," Mentzel and Von Lengerke's landwirtschaftliche Kalender and those by A. C. Whittier are from this laboratory. In these last, the sulphur determinations were made by fusion of the fresh substance.

In this table on page 44, we state the amounts of the various mineral elements contained in 1000 parts of dry substance. In the third and fourth columns of figures from the right, we state the total amount of acid minerals and of basic minerals computed to normal solutions, that is, so that one cubic centimeter of acid will exactly neutralize one cubic centimeter of base. Phosphoric acid is considered to be neutralized when two of its hydrogen atoms are replaced by a base.

In the two columns on the right side of this table is stated the excess of acid or base, as the case may be, in cubic centimeters of normal solution in 1000 grams of dry substance. To reduce any of the figures to the fresh or air-dry basis, multiply the numbers as stated by the dry substance expressed as percent.

This excess of acid or base as stated in the table is obtained by subtracting the total amount of acid (phosphoric, sulphuric and hydrochloric) from the total amount of base, (sodium, potassium, calcium and magnesium.)

Thus we ascertain the nature of the active or unsatisfied excess of mineral matter, that is, whether it is base or acid. The rest is like a balanced account, debits equaling credits.

The excess, if of alkali, may be considered to represent carbonates or organic compounds such as upon oxidation yield carbonates of alkalis (sodium or potassium) or of alkaline earths (calcium or magnesium); if of acid it may be considered to represent acid-reacting elements such as upon oxidation yield free mineral acids.

In spite of the wide range of variation which there is in the composition of the ash of organic substances, in accordance with differences in species or environment, a general agreement as to balance between acid and basic minerals in foodstuffs of the same class, is apparent.

From these figures it would appear that the ash of milk is markedly alkaline and from this it is probably safe to conclude that the food of animals should possess an excess of mineral bases in the ash. This assumption seems particularly justifiable when we consider the fact that on the basis of Lawes and Gilbert's work, mineral base predominates in the ash of animal bodies and further when we consider the probability as shown by Soxhlet⁴⁶ that the calcium content of milk constitutes the limiting factor in the production of growth and that the storage in growing animals is more largely of basic than of acid mineral elements.

Black albumen, No. 5 in the table, a packing-house by-product, is the first separation of serum from blood-clot in the preparation of the clear, dried serum used in dyeing. We use this black albumen as a low-phosphorus proteid in nutrition experiments. It is rich in sodium, magnesium, sulphur and chlorine and has an acid ash.

Beef, pork and chicken flesh all have acid ash and Sherman calls attention to the fact that carnivora make good the deficiency of mineral base in flesh by the consumption with it of parts of the bones. As an only food, flesh undoubtedly possesses an excess of acid mineral elements.

The white of egg has a strongly alkaline ash while the ash of eggs as a whole, without the shell, is slightly acid.

We should not argue, however, that because mineral acids slightly predominate over mineral bases in eggs, animal food should possess a like excess of acid, since the egg is not food in the sense in which milk is food. The egg is potentially a complete being in itself, merely requiring transformation into the more highly specialized tissues of the fully formed animal and maintenance during the process. There is neither the necessity nor the provision, as in milk, of adaptation to the processes and activities of the digestive tract of the animal to be nourished.

Fruits and vegetables have, without exception, strongly alkaline ash. Their natural acidity is due to organic acids which are oxidized in the body and excreted as carbon dioxide and water.

Beets, cabbage, rhubarb, spinach and tomatoes have exceedingly alkaline ash, the excess of alkali ranging from one cubic centimeter of normal solution in beets, to three and seven-tenths cubic centimeters per gram of dry substance in tomatoes.

Potatoes, onions and asparagus are also conspicuously basic as to ash, but in a class decidedly second to beets, cabbage, rhubarb, spinach and tomatoes.

Fruits also are unmistakably basic as to ash, apricots and oranges containing considerably more than half a cubic centimeter of excess normal base per gram of dry substance, while figs come a little under this mark and apples, plums and raisins are in a second class as regards alkalinity of the ash.

Of the cereals, wheat appears to be slightly acid, as are also white bread and graham bread, gluten flour, corn, pearl hominy and oat meal. Further work will doubtless show that the measure of acidity in most of these cases is low. Oats here appear to have an alkaline ash, doubtless due to loss of acid minerals; corn bran has a slightly alkaline ash and wheat bran is, on the basis of the evidence at hand, doubtful as to reaction of the ash. The cereals are usually considered to have an acid ash and as is well known, do not support normal growth of bone.

Magnus-Levy⁶ says: "A part of the vegetable foods of man, the cereals, yield (just as does flesh) an acid ash, whereas the grasses and herbs of herbivora yield an alkaline ash. Cereals are equivalent to animal food in respect to the metabolism of the ash."

In corn there is a decided excess of acid minerals over basic minerals and the total ash of corn is also low. Both of these factors may contribute to the production of acidosis by corn, as also may the disproportionate excess of magnesium in comparison with the small amount of calcium present. As in corn, so in bran, the magnesium content is greatly in excess of the calcium, while, for structural purposes and for milk production, very much more calcium than magnesium is needed.

In spite of the richness of bran in mineral matter the existence of "bran disease" or "miller's horse rickets" indicates that its mineral nutrients are in some way out of balance.

Mendel and Benedict⁴⁷ find that the injection into an animal of either calcium or magnesium salts, leads to an increased excretion of the other, (calcium if magnesium has been injected or the reverse), by the kidneys.

J. Malcom⁴⁸ comes to the conclusion that the ingestion of soluble magnesium salts causes a loss of calcium in adult animals and hinders its deposition in young, growing animals, but that soluble calcium salts do not in the same way affect the excretion of magnesium.

Beans, soja beans, linseed oilmeal and cottonseed meal are all high-proteid foods and their sulphur contents should be correspondingly high. The evidence hardly warrants drawing conclusions as to the balance of minerals in the ash of these foods.

The various hays and straws appear to have strongly alkaline ashes. Clover and alfalfa, however, largely because of very high lime contents, have much more alkaline ashes than have the grass plants.

While it is universally recognized that clover or alfalfa, with corn, constitutes a ration, for farm animals, which cannot be greatly improved, especially for the production of increase in weight, still it is not so generally understood that the high content of these legumes in mineral bases generally and calcium in particular, constitutes an important factor in the superiority of these feeds as supplements to corn. This, however, is undoubtedly true since these legumes are characteristically rich in those mineral nutrients which are lacking in corn.

A comparison of some of the above figures with recent work by Sherman and Sinclair⁴⁹ indicates that the estimates of the acid mineral elements of wheat, oatmeal and milk are probably decidedly low, though in each case the balance would remain on the same side of the account as indicated by the figures which we quote.

This balance between acid and base in foodstuffs may be modified, before these nutrients reach the tissues, by certain influences in the alimentary tract. Thus according to Albu and Neuberg¹⁴ the amount of calcium absorbed from the intestine is influenced by the other salts present, sodium chloride increasing its resorption and alkalis diminishing it. The formation of difficultly digestible calcium soaps in the intestine may also alter the balance between the acids and bases resorbed. Further, variations in the solubility and resorbability of the salts in the various articles of the dietary tend to render definite conclusions difficult; and calcium from vegetable foods is much less completely absorbed than the calcium from flesh.

It is also impossible closely to estimate the proportion of the mineral bases that will leave the body in combination with organic acids in the urine. To be entirely accurate it would also be necessary that we leave out of consideration such portions of the organic sulphur and phosphorus of the food as leave the body in organic combination; also that we consider in a more definite way than is now practicable, such organic acids as leave the body in combination with mineral bases, and further that we consider the fact that some phosphorus leaves the body as acid phosphates, that is, without carrying

with it enough inorganic base to render it neutral. There is, however, a compensating factor, since some phosphorus leaves the body carrying more than enough mineral base to render it neutral.

Is it a matter of importance whether this balance be maintained at a high or a low level? The excess of either acid or base might be the same in a food very poor in both as it is in one very rich in both.

In answering this question we must bear in mind the fact that excess of acid or base is but one of the many factors affecting the usefulness of the mineral elements as animal nutrients. All of those minerals which are of use in the body as neutral inorganic salts, might be withdrawn from a ration without altering in the slightest degree the excess of either acid or base. The great majority of the functions of the mineral elements in the body are served in accordance with the amounts and kinds of minerals present, and quite irrespective of any excess of bases or of acids, unless such excess interferes with normal processes. (See note.) Thus it appears that it is a matter of great importance that the balance be maintained at a high level rather than at a low one.

SUMMARY.

The organic acids of foodstuffs, such acids, for instance, as the citric, malic and tartaric acids of fruits, are mostly oxidized in the animal body to carbon dioxide and water, in which compounds they are excreted; but there are formed within the body, mineral acids which cannot be decomposed and eliminated in this way. These acids must be neutralized in order to protect the animal from a disturbance of conditions essential to the continuance of vital reactions.

These acids are formed chiefly by the cleavage and oxidation of the proteids, either of the body or of the food, the sulphur and phosphorus contained therein, as constituent parts, being oxidized to the corresponding inorganic acids.

These acids are neutralized,

- (1) by carbonates of the food, water or tissues;
- (2) by alkalis liberated by the oxidation of organic-acid salts;
- (3) by ammonia withdrawn from the constructive formation of urea;
- (4) by ammonia from the tissues;
- (5) by ammonia splitoff from proteids, especially for acid-neutralization.

Both acid and base are also liberated in slight amounts by the decomposition of sodium chloride in the formation of gastric juice.

NOTE: For information relative to the amounts of the various mineral elements required by animals the reader is referred to Kellner's "Ernährung der landwirtschaftlichen Nutztiere," to Von Noorden's "Metabolism and Practical Medicine" and to Bul. 201 of this Station.

The continued neutralization of excessive amounts of acids by some of these means, especially by use of the carbonates of the bones, may mould the whole style of development of a growing animal; may cause serious states of malnutrition and may act as contributory causes of a number of diseases of both Man and other animals.

In case the acids formed within the body or introduced into it exceed the animal's capacities to neutralize them, death may ensue with symptoms of asphyxia, or suffocation, due to disturbance of the equilibrium of salts of the blood plasma, upon which depends the capacity of the blood to carry carbon dioxide from the tissues to the lungs.

The practical bearing of the subject is on the feeding of such animals as are reared most largely on cereals, namely, swine and poultry; especially on the growth of the bones of animals; on acidosis in infants; and on the care of sufferers from rickets, osteomalacia, osteoporosis, bran disease and diabetes.

In this connection we consider especially the acid mineral elements, sulphur, phosphorus and chlorine, and the basic mineral elements, sodium, potassium, magnesium and calcium.

The relative amounts of mineral acids and bases formed in the body may be greatly modified by a choice of foodstuffs.

Fruits, vegetables, roughage and milk have alkaline ash; meat, eggs, cereals and many cereal foods and by-products have acid ash.

Corn has an acid ash and is also particularly deficient, as a food, in calcium and also in total mineral content.

In straight corn-feeding we see the resultant of a complication of deficiencies; corn lacks protein as well as minerals. In the ash, both acids and bases are deficient but the bases considerably more so than the acids, so that as an only food, corn is characterized by an excess of acid mineral elements and this excess, together with the deficiency in the total amount of mineral matter present, limits the growth of the skeleton; but if the protein in the ration of the corn-fed animal is increased by the use of supplements, to such extent as will support maximum production of proteid increase, then both phosphorus and the mineral bases must be increased.

The basic mineral elements in a ration must be present in quantities corresponding to the protein, since the sulphur and phosphorus of the food proteins constitute the principal sources of mineral acids in the body.

It is important not only that there be a considerable excess of mineral bases in the food but also that this excess be maintained at a high level, that is, that aside from the balance between acid and base, the total quantity of ash should be considerable.

The capacity of the animal body to neutralize and eliminate alkali seems to be entirely adequate. In practice animals do not experience injurious excess of alkali as they do excess of acid.

Consumption of a needless amount of protein unnecessarily taxes the acid-neutralizing capacity of the animal and if carried to a sufficient extreme, results either in discouragement of the formation of bone or in malnutrition of the bones.

A high fat-content, or indigestible character of the fat of milk fed to infants suffering from digestive disturbances, causes acid intoxication by withdrawal of alkalis, by way of the feces, in the condition of difficultly soluble calcium soaps.

Because of the alkaline ash of the milk of all animals, it is assumed that other food of animals should have an alkaline ash.

Any such circumstances, as drought, or poverty of the soil in calcium and phosphorus, as tend to diminish the content of the forage in these elements, at the same time limits the growth of the bones and favors the development of diseased conditions in the animals consuming them.

No animals which consume fruits, vegetables, milk or roughage in sufficient proportion to other food are likely to suffer from an excess of mineral acids in the body. Animals fed too little else than meat, eggs, and cereal foods, including bread, are more likely than others to suffer from an excess of inorganic acids or a deficiency of inorganic bases.

Growing animals, when fed for protracted periods on either cereals or meat alone, suffer from malnutrition of the bones, this ailment being caused by the deficiency of these foods in mineral bases.

Swine, because of their very rapid growth, have especial need for calcium in the food, as is indicated by the unusual richness of sow's milk in calcium. Corn contains less calcium than other common grain foods and on that account is less perfectly adapted to serve as an only food for swine.

Clover and alfalfa are especially rich in calcium and hence serve to make good the deficiency of corn in this element.

ARTICLES CITED.

1. Sherman: Office of Exp. Sta. Bul. 121.
2. Neuberg and Grosser: Zentralbl. für Physiol., vol. 19, No. 10.
3. Stadelman: Experimental Archiv, vol. 17, p. 419.
4. Henderson: Am. Journ. Physiol, vol. 18, p. 113; vol. 21, p. 169; vol. 21, p. 420.
5. Magnus-Levy: Von Noorden's Metabolism and Practical Medicine, vol. 1, p. 86.

6. The same, vol. 1, p. 41.
7. The same, vol. 1, p. 84.
8. Folin: *Am. Journ. Physiol.*, vol. 13, p. 92.
9. Drechsel: *Chemisches Berichte*, vol. 23.
10. Walther: *Experimental Archiv*, vol. 7, p. 148.
11. Voegtlin and King: *Journ. Biol. Chem.*, vol. 6, No. 2, p. xxviii.
12. Forbes: *Bul. 81, Mo. Agr. Exp. Sta.*
13. Albu and Neuberg: *Mineralstoffwechsel*, Berlin, 1906, p. 113.
14. The same, p. 112.
15. The same, p. 117.
16. Naunyn: *Der Diab. mell.*, 1898.
17. Magnus-Levy: *Experimental Archiv*, vol. 42, p. 149.
18. Hirschfeld: *Zeitschr. f. klin. Med.*, vol. 28, p. 176.
19. Rey: *Experimental Archiv*, vol. 45, p. 295.
20. Wellman: *Archiv f. Physiol. (Pflüger)* vol. 121, pp. 508-533.
21. Patterson: *Bio-Chem. Journ.*, vol. 3, pp. 39-54.
22. Forster: *Zeitschr. f. Biol.* vol. 9.
23. Bunge: *Zeitschr. f. Biol.* vol. 10, p. 120.
24. Lunin: *Zeitschr. f. physiol. Chem.*, vol. 5, p. 31.
25. Kemmerich: *Archiv f. Physiol.*, (Pflüger), vols. 75 and 79.
26. Salkowski: *Virchow's Archiv*, vol. 53.
27. Walter: *Arch. f. exp. Path. u. Pharm.*, vol. 7.
28. Watson: *Lancet*, Dec. 8, 1906 and *Proc. Roy. Soc. Edinb.*, vol. 27, No. 1, pp. 2-5.
29. Forsyth: *Journ. Physiol.*, vol. 35, 1902, No. 5-6, pp. 40-41.
30. Spriggs: *Journ. Physiol.* vol. 36, 1907, No. 1, p. 17.
31. Weiske: *Zeitschr. physiol. Chem.*, vol. 20, p. 595; *Maly's Jahresber.*, vol. 22; *Zeitschr. f. Biol.*, 31.
32. Magnus-Levy: *Zeitschr. f. physiol. Chem.*, vol. 19, p. 239.
33. Mohr: *Von Noorden's Metabolism and Practical Medicine*, Chicago, 1907, vol. 3, p. 1263.
34. The same, vol. 3, p. 1274.
35. Mohler: *Bu. An. Ind. Circ.* No. 66, 1904.
36. Law: *Text Book of Vet. Med.*, vol. 3, p. 574.
37. Friedberger and Fröhner: *Pathol. and Ther. of the Dom. Animals*.
38. Mohler: *Am. Vet. Rev.* May, 1907.
39. Bitting: *Bul. 26, Florida Agr. Exp. Sta.*
40. Hammarsten: *Text Book of Physiol. Chem.*, 1906, p. 368.
41. Ingle: *Journ. Agr. Sci.*, vol. 3, part I, p. 22.
42. Hutcheon: *Agr. Journ. Cape of Good Hope*, vol. 24, No. 4, p. 540.
43. Czerny and Steinitz: *Von Noorden's Metabolism and Practical Medicine*, Chicago, 1907, vol. 3, pp. 833-896.
44. Kellner: *Centralbl. f. innere Med.*, 1898, No. 21.
45. Steinitz and Weigert: *Beiträge zur chem. Physiol. und Pathol.*, vol. 6, p. 206.
46. Soxhlet: *Bericht über Arbeiten der landw. Versuchsstationen Wein*, 1878, p. 151.
47. Mendel and Benedict: *Journ. Biol. Chem.*, vol. 4, No. 2., 1909.
48. Malcom: *Journ. Physiol.*, 1905, vol. 32, p. 182.
49. Sherman and Sinclair: *Jour. Biol. Chem.*, vol., 3 p. 307.
50. A. P. Mathews: *American Journ. Physiol.*, vol. 18, p. 58.

BULLETIN

OF THE

Ohio Agricultural Experiment Station

NUMBER 208

AUGUST, 1909

PROTECTION OF FRUIT TREES FROM RODENTS

By F. H. BALLOU

PREFACE



ACCORDING to the Official Report of the Ohio Department of Agriculture for 1907, there are, in the state, 266,340 acres of tree fruits including all classes. Of those classes more subject to tree injury by rodents, viz., apple, pear and plum, there are 247,700 acres. Of apples alone there are 243,716 acres. This great acreage includes not

only the extensive commercial plantations, but the thousands of small, home orchards, scattered in every part of the state.

There are no data available which would render possible anywhere near a correct estimate of the loss of and injury to trees, young and old, through the work of rodents (mice, rabbits and woodchucks) in Ohio. While the loss is confined principally to newly set orchards, replants in older orchards and the younger plantations generally, this loss, in the aggregate, is considerable. It certainly would not be far beyond the bounds of conservatism to figure the loss and injury at one dollar per acre per year including all ages and conditions of the apple, pear and plum orchards of the state. The rate of loss would be less than this in the larger commercial plantations, even where the grass-mulch method of culture is practiced; for the commercial planter generally takes into consideration the various sources of danger and makes provision to

meet these with effective means of protection. With the average home orchard the danger is greater than in the large plantation, and the possible means of protection more generally disregarded or over-looked.

Thus do we find, by a very simple calculation, that there is probably incurred, annually, the astounding loss of over \$200,000 in Ohio, from the work of the sharp teeth of bark-eating rodents, and those of mischievous and destructive habits.

Much complaint has been received by the Horticultural Department of the Experiment Station, of the injury and loss wrought by rodents, and repeated requests for suggestions as to effective means of protection of young and newly set orchards have been received. In many cases bearing trees are reported killed by mice.

In order to fully meet the demands of the planting public, this illustrated pamphlet has been prepared, which is the first of a series of purely practical bulletins planned to be issued in the future by the Horticultural Department of the Station. This series of bulletins will present in popular form that class of information so eagerly and persistently sought by the hundreds of beginners in horticulture who write to the Station for suggestions and assistance.

I. A TRUE ORCHARD INCIDENT

Accompanied by a little daughter who is deeply interested in and delights in trees, plants and flowers and the furred and feathered families which make their homes among them, the writer visited a certain section of our young apple orchard growing under the grass-mulch method of culture on a steep hill-slope at "Dale View." It was in the late summer of 1908, the season at which the owners of young trees should plan for protection from rabbits, which often begin testing the sharpness of their teeth as early as November, while there is yet an abundance of green vegetation upon which to feed.

The first tree visited was one which had been top-grafted in the spring of 1908 with a rare, new variety. While admiring the growth of this young tree the loss of which would be a very serious matter indeed, the observing eyes of the little girl detected a bit of rabbit fur clinging to the grass stems nearby. Here was a recognized clue to something of interest to a youthful lover of nature. A short search followed and its object was discovered.

"Baby rabbits—come and see!" Parting the bluegrass and white clover she exposed four little, frightened balls of fur shrinking down in the small, grass-lined excavation in the ground.



Fig. 1. "Baby rabbits—Come and see!"

Here, indeed, was an orchard problem! Within five feet of the base of the almost priceless tree and surrounded by other young trees of value, was a quartette of youthful representatives of a formidable orchard pest. "To kill or not to kill" might naturally become the question in the mind of the orchardist under these circumstances. Should the enemy be diminished by four at a single stroke, or *should the tree be protected and the enemy spared?* The question in this instance was submitted to American girlhood for decision.

The verdict was rendered without debate. *The tree was protected—so was the enemy!* The one to continue growth unblemished with promise of fruitful days to come; the others to rapidly outgrow their period of innocence and harmlessness and develop into agile, rollicking, mischief-working rodents which inspire no further real appreciation until “bagged” by a careful gunner; then, at last, they “promise to be good”—served on the table of the orchardist.



Fig. 2. Should we slay the enemy or protect the tree?

II. FURTHER DISCOVERIES

Let us resume our visit of inspection in this young orchard. Here is a row of trees six or seven years of age which has, in a measure, outgrown the period of danger of injury by rabbits. Dare we allow ourselves to feel secure in considering these beyond the need of further attention. By no means! They had been heavily mulched with grass cut from between the rows in June; but up through this mulch are pushing, here and there, sturdy growths of rag-weed, yarrow, sorrel and other strong-growing weeds which, together with the decaying material of the mulch beneath, provide excellent hiding places and covers under which the field or meadow mice will work when winter comes, if not before.

Let us draw back the mulch from about the stems of a few of the trees and see what may be found. Many “runs” and burrows of field mice are thus exposed, but the trees, so far, seem to be

untouched; for it should be remembered that proper precautions had been taken each autumn previous to protect these same trees from winter injury by mice. We are just about to congratulate ourselves that our young orchard is unblemished when we examine a much-prized tree of the Benoni apple and find it almost completely girdled. There are even *fresh* marks of mischievous, little teeth, impressing us with the truth that we should not consider our mulched trees safe from these little rodents even in the summer season.



Fig. 3. The tree was protected—so was the enemy!

Resuming our way through a younger portion of the orchard we come upon a little tree whose stem is scarred by deep, jagged wounds where the powerful jaws and vicious, cutting teeth of some rodent have been exercised. The bark has not been eaten as by rabbits or mice—only terribly mutilated. The destructive work is at once recognized as that of a trespassing woodchuck or “ground-hog” whose freshly made burrow is found nearby.

Farther up on the hillside other mounds of fresh earth clearly show that a colony of these troublesome rodents is establishing itself and forcing upon us many destructive and unwelcome guests.

With the patience and cunning that in time become characteristic of the devoted photographer, we succeed in catching, with the camera, a very-much-alive "chuck" indulging in a day-dream in the

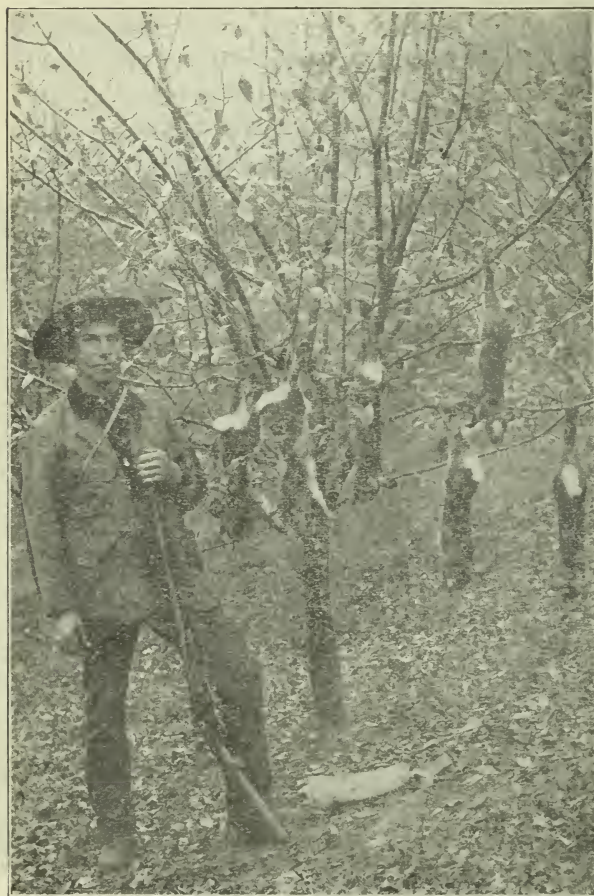


Fig. 4. They promise to be good.

entrance to his burrow. (See frontispiece).

Later this same burrow shall have dropped into its deep passage a small ball of rags or twine saturated with bisulphide of carbon, after which the entrance must be closed securely with a banking of soil firmly tamped or pounded. The deadly penetrating vapor or gas from this dangerous, explosive chemical, will fill the burrow and the inmates will lapse into a sleep during which there will be no dreams of mischief for the future.

III. OBJECT LESSONS IN TREE PROTECTION

As an object lesson in tree protection, a row of young trees in this young orchard was fitted with the various types of mechanical protectors now known and used by various horticulturists. These are shown by photographs on the following pages and are accompanied by brief descriptions and remarks which will readily enable the planter to decide which form or means of protection will best suit his conditions.

BANKING WITH SOIL OR CINDERS

The soil or cinder mound as a protection against tree injury by field mice is first described, not only because it is quite effective in itself, but because it is recommended in conjunction with various other mechanical protectors designed to prevent injury by the larger rodents.

Mice rarely injure trees except where grass, strawy manure, boards or trash of some kind about the base of the tree provide a hiding place; they will not come out into the open to work, but choose to perform their depredations under cover.

In mounding fruit trees for protection from mice there are three important points to observe:

First, clear away the grass, trash or mulch from the base of the tree for a foot or more in all directions.

Second, with the foot, or, better with a "post tamper," thoroughly firm the surface of the soil about the base of the tree. This breaks down and fills any runs or burrows that may be just below the surface.

Third, with a few shovelfuls of fresh soil or cinders form a small mound (twelve or fourteen inches in diameter at the base and from 4 to 6 inches high) about the stem of the tree, firming the soil well.



Fig. 5. Where danger lurks.

The tops of these small mounds are usually kept quite bare by the sweeping force of the winter winds, even if there be several inches of snow on the ground. Mice will not venture out on these exposures to feed on the bark of the trees; and burrowing into the freshly packed soil is not likely to be attempted in the winter, even in open weather.



Fig. 6. Vicious work of woodchucks.

The mounds may be left throughout the year, but they should be tamped hard and repaired by the addition of fresh soil each autumn.

Where cinders are available these are a most excellent and inexpensive material with which to mound the stems of all kinds of fruit trees. Mice will not burrow through the cinders as they do through soil.

THE WIRE SCREEN

This is the ideal and complete, all-round protector and it is, therefore, given first place among the mechanical forms. True, it is more expensive than many others, but it is lasting and thoroughly effective against all kinds of rodents which prey upon the stems of young trees. Being so light and open, it presents the least obstruction to strong winds; the air and sunshine are freely admitted; no dark and secure places of concealment, such as invite woolly-aphis and other forms of insect life are afforded.

This protector is made of galvanized wire cloth of one-quarter inch mesh (four 22 gauge wires to the

inch) which may be purchased from the larger supply houses in rolls of one hundred lineal feet and in any width from twenty-four to thirty-six inches.

For apple trees the 24 inch width is usually the more convenient size. This is cut crosswise with tinner's snips or shears into 12-inch sections, making pieces 12 x 24 inches in size. These sections are

carefully bent or rolled over a small, round piece of wood (a section of broom or fork handle will answer) shaping them into cylinders $2\frac{1}{2}$ to three inches in diameter. It is well to allow the edges to lap about one inch.

The cylinders are placed about the stem of the trees where their own tension will close them securely.

At the present quoted price of \$3.00 per roll of 100

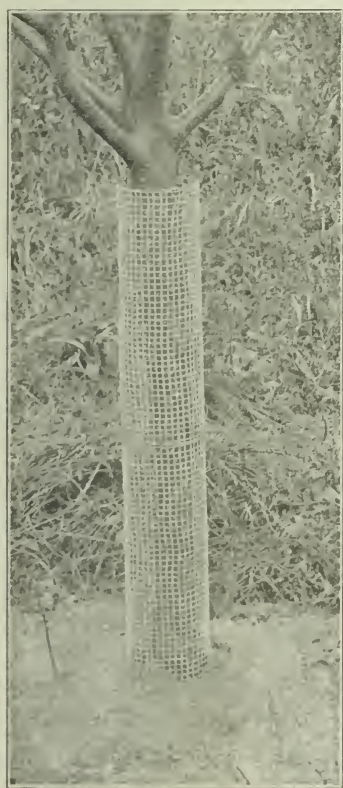


Fig. 8. The wire screen.



Fig. 7. The soil mound.

lineal feet for 24 inch wire cloth, protectors of the dimensions given will cost \$3.00 per hundred aside from the work of cutting and shaping them, which anyone handy with tools can readily do.

SMALL MESHEd POULTRY NETTING

This protector is made of ordinary weight, galvanized wire poultry netting of one inch mesh. This is quite as effective against rabbits as the closer-woven wire cloth, but will not protect the trees

from mice. This netting may be purchased in bales of 150 lineal feet and cut and shaped just as described for the wire cloth. The



Fig. 9. Small meshed poultry netting.

mice. In combination with a slight mound of soil about the base of the tree, mice will rarely prove troublesome.

STANDARD POULTRY NETTING

It often happens that the planter of a few trees has at hand a quantity of old poultry netting of standard or 2-inch mesh. From this stock in hand quite serviceable protectors can be made by cutting out sections 18 x 24 inches in size and rolling them around a section of broom handle as described. The mesh being so large, the pieces are cut six inches wider than

present price of the 24 inch wire is \$3.30 per bale. This style of protector would, therefore, cost \$2.20 per hundred. These are very neat and sightly and do admirably for cultivated orchards, or wherever the method of culture or the environment does not favor the presence of field



Fig. 10. Standard poultry netting.

in Figs. 8 and 9 in order that there may be at least two rounds of the netting encircling the stem of the tree. Rabbits and woodchucks will not be able seriously to injure a tree thus protected. This form

presents no obstacle to the work of mice; but mounding slightly, in connection, will baffle these little pests. Made from new stock 24 inches wide, purchased by the bale of 150 lineal feet, this style would at present prices, cost \$1.50 per hundred protectors.

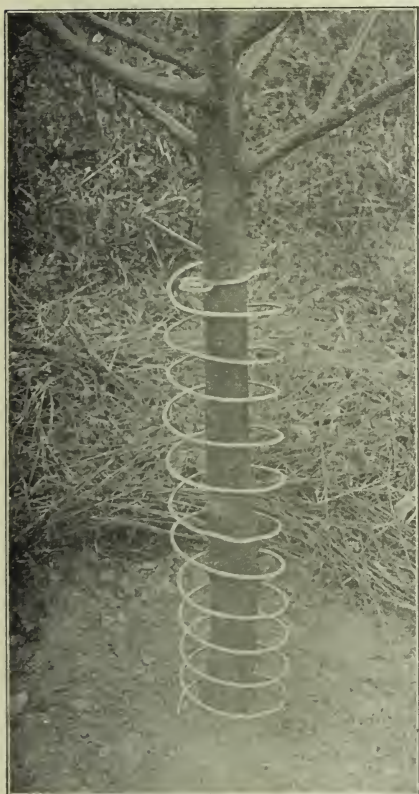


Fig. 11. The spiral coil.

THE SPIRAL WIRE

Spiral protectors of heavy wire have been offered on the market for some years, but there are few used in Ohio. While effective against rabbits, they are of no avail against mice except as the trees are mounded. Hence this form is not superior in any way to the wire netting protectors already described.



Fig. 12. Wood veneer.

WOOD VENEER

This style is effective against all kind of rodents; but, as they form a tight, close, light-excluding cylinder, various forms of insect life thrive in the crevices and under the cover thus provided. The woolly aphis or root louse, when present in the orchard, increase in great numbers on the bodies of the trees under such covers. While the

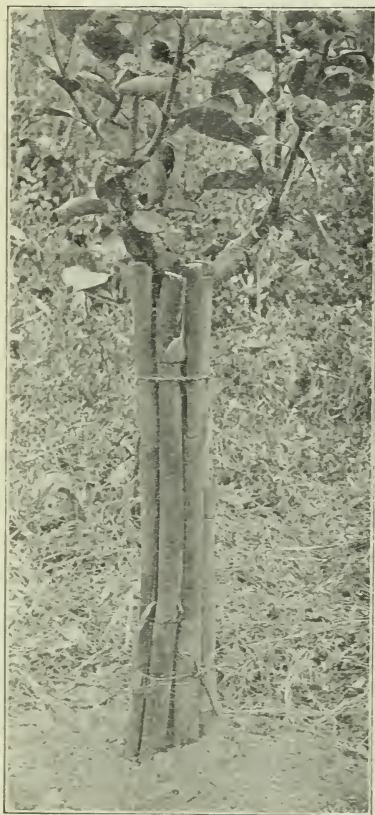


Fig. 13. Corn stalks.

veneers are excellent protectors for the winter season, both from injury by rodents and from winter injury to the stems of the trees, they should be removed during the summer season. The different forms of wire cylinders are preferred.

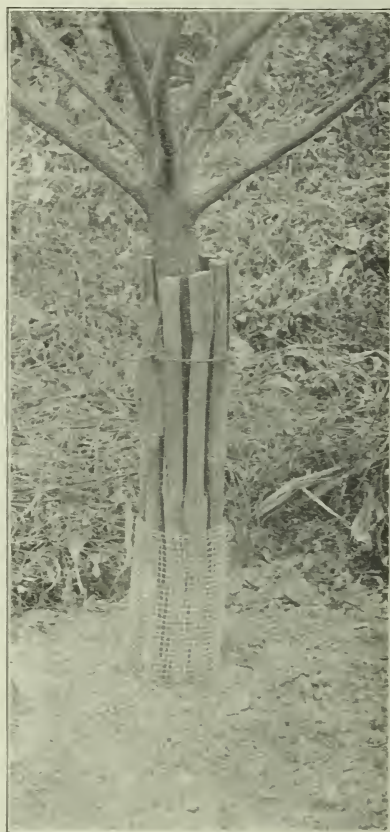


Fig. 14. Wire cloth and corn stalk.

CORN STALKS

There is no device superior in effectiveness against rabbits and groundhogs than this, and certainly none cheaper for the farm orchard. There is practically no cost of material where corn is

grown or cornstalks fed. A good plan is to take the bundles of stover as they come from the field, before feeding to the stock. Lay the bundle on a low platform or broad, low box, and "square-off" the butts with an ordinary "Lightning" hay knife. A solid block and a broad-ax may be made to answer, but the hay knife is much better. Next cut off a two-foot length of the lower ends of the stalks in the same way. These sections may be fed to the stock either in a manger or in the feed-lot, where the blades will be cleanly and neatly stripped off. After a few days' feeding several hundreds or even thousands of these uniform length stalks may be rapidly gathered up and tied in bales for future use. Five or six stalks bound firmly about the stem of a young tree, with twine or short sections of baling or broom wire, as shown in the picture Fig. 13, will constitute a protector that will last not only for one season, but for several or as long, usually, as the tree needs protection from rabbits. The stalks readily yield as the stem of the tree increases in size. In case wire ties are used for binding on the stalks, great care should be exercised to see that these are removed from about the tree when the stalks are taken off. If not removed they will drop down about the collar of the tree and become covered with soil and forgotten. Trees have been killed by wire girdling in this way.

By mounding the bases of the trees slightly with fresh soil and firming it well, a stalk-protected tree is quite secure from all rodent enemies.



Fig. 15. The short, wire cylinder.

COMBINATION WIRE CLOTH AND CORN STALKS

This form will appeal to the most exacting. The stalks protect the stems from rabbits, while the 8-inch wire cloth cylinders, cut from the same material in Fig. 8, completely baffle the mice even in badly infested orchards. The wire cylinders should be forced down two or three inches in the ground. These cylinders are formed from sections of wire cloth 8 x 12 inches in size. Cost, about 1 cent each.

THE SHORT, WIRE CYLINDER

When trees have attained the age of six or seven years they are usually beyond the period of injury by rabbits. We then have to protect only against mice. The short, galvanized wire cloth cylinder alone, well imbedded in the soil about the base of the tree, is quite sufficient even in badly infested orchards, except when unusually deep snows come and lie a considerable time on the ground. It may then be well to tread down the snow immediately about the trees to prevent mice burrowing about and feeding upon the stems above the protectors.

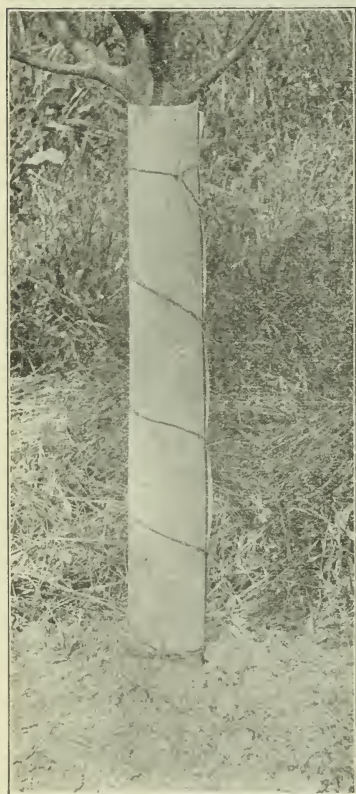


Fig. 16. The simple paper cylinder.

THE SIMPLE PAPER CYLINDER

In combination with the soil or cinder mound, paper wrappers of different kinds are temporarily effective in protecting from rabbits; but these protectors should be removed during the summer season because of the fact that they afford excellent places for concealment of the larvæ of certain insects and for the woolly aphis.

A simple paper cylinder formed of ordinary printing, wrapping or even newspaper, will serve well for a single winter. The picture above shows clearly the manner of applying and tying in place. All paper wrappers should extend a little below the surface of the soil at the base.

BUILDING PAPER

A good grade of building or "sheathing" paper is, of course, preferable to wrapping or newspaper for tree protection. According to grade, these heavier wrappers should cost but from one-tenth to one-fifth of a cent each or 10 to 20 cents per 100, if the paper be purchased by the roll of 500 square feet. These may be put on the trees



Fig. 18. Combination wire cloth and building paper.



Fig. 17. Building paper.

in the form of a plain cylinder, or the paper may be cut into strips from four to six inches wide and wrapped spirally about the stem to the desired height, beginning at the base and fastened with twine in the usual way.

There are two points of superiority in the plan of spiral wrapping, over the cylindrical protector; first, a crooked bodied tree can be closely and neatly covered (see picture above); second, the

spiral wrapper is more resistant to the strong winds of winter which sometimes play havoc even with building paper protectors if not securely fastened with twine spirally applied.

COMBINATION WIRE CLOTH AND BUILDING PAPER

This protector, put on as shown in the picture, is trustworthy under almost all conditions. The wire screen discourages the mice while the paper wrapper is accepted by the rabbits as an invitation

to look elsewhere for forage. The paper may be removed and the screen retained during the growing season.

ANIMAL BLOOD

Fresh blood from a slaughter house, applied as a paint to the stems of trees in autumn and again in mid-winter, will prevent the work of rabbits. Or, the bodies of the trees may be well rubbed with a piece of fresh pork or beef liver with the same results. These remedies are not effective against mice, however, and should be used in connection with banking or screening the bases of the trees.

Various repulsive and unnamable mixtures have from time

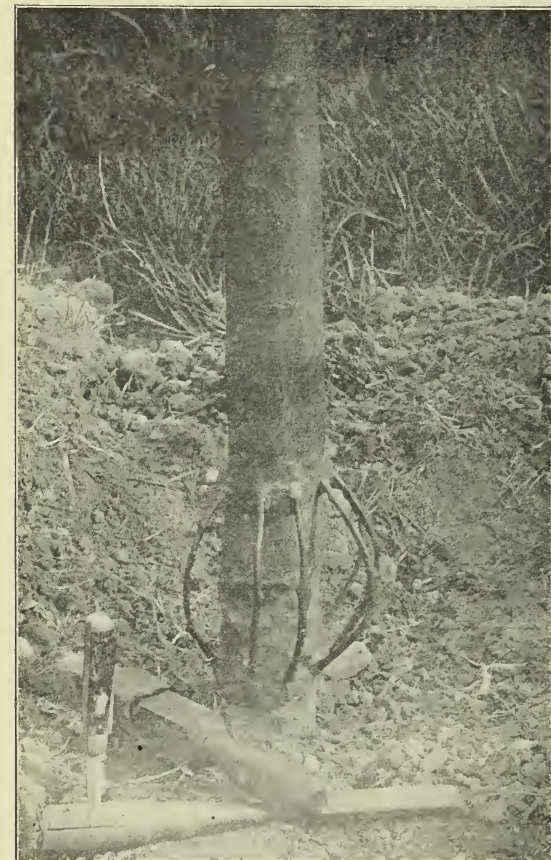


Fig. 19. A bridge-grafted tree.

to time been recommended as against the work of rabbits, but the above is just as servicable, and much more cleanly to apply.

AN EFFECTIVE WASH

A thick paint of lime, soap, carbolic acid and sulphur is recommended to protect fruit trees from injury by rabbits, sheep and mice. It is made as follows: Slake one peck of fresh, stone lime

with old soap-suds, thinning to the consistency of whitewash. For the one peck of lime add one-half gallon of crude carbolic acid, four pounds of sulphur and one gallon of soft soap. Paint the trunks of the trees with this in late autumn.

THE MODERN LIME-SULPHUR MIXTURE

It has been found that the lime-sulphur mixture, such as is used for spraying for scale insects, is quite effective in preventing work by rabbits in the orchard and nursery. This is the ordinary 15-15-50 boiled mixture with which nearly all home owners are now familiar. It is used as an autumn spray, the stems of the trees being thoroughly covered with the mixture entirely to the ground.

For those who desire to prepare a small quantity of the lime-sulphur mixture for a few trees, to be used as a paint, the following will be helpful:

Slake one pound of fresh, stone lime in a small quantity of hot water. Or, one pound of ordinary hydrated or "prepared lime may be used instead.

Boil for one hour the one pound of lime with one pound of sulphur in one gallon of water. Thin the boiled mixture with enough hot water to make three and one-third gallons. This should be used while fresh, keeping it well stirred.

CONCLUSION

If young trees be girdled in late spring just as growth is beginning, they may be successfully treated by binding about the wounded parts a heavy covering of smooth tenacious soft clay. A new bark will sometimes

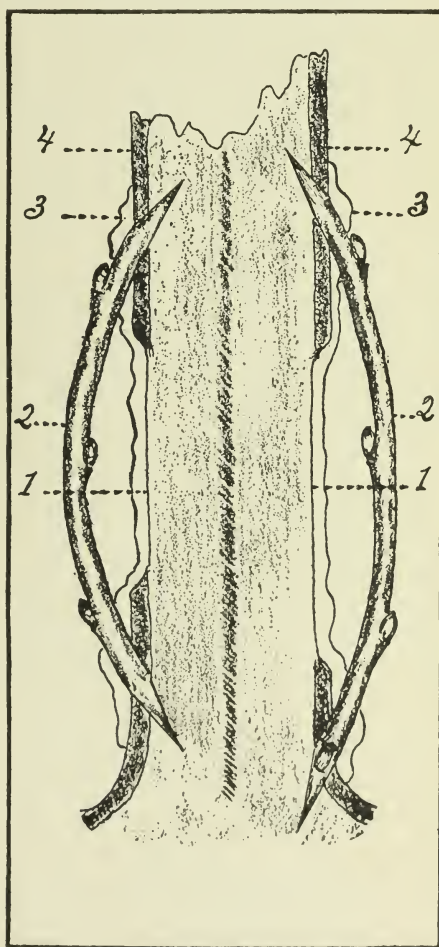


Fig. 20. Bridge-grafting in detail.

- | | |
|-----------|-----------|
| 1. Wound. | 2. Scion. |
| 3. Wax. | 4. Bark. |

form beneath the clay if the inner bark or cambium be not entirely destroyed. It is safer, however, to insert a few long scions as shown in the accompanying picture.

This is called "bridge-grafting." The sap circulation of the tree, cut off by the wound made by the rodents, is resumed through the scions which become a part of the tree—enlarging and growing together until, in after years, only a slight enlargement or "bulge" on the trunk of the tree thus treated will be noticeable.

In bridge-grafting, the wounds should be made clean and smooth with a sharp knife and covered entirely with grafting wax. The scions should be cut a trifle longer than the span to be bridged so that, when they are inserted, their curving form will tend to keep them firmly fixed in position. The two ends of the scions are cut to a thin, wedge form. Incisions are made in the bark with a narrow chisel—those above the wound sloping upward and those below sloping downward. Insert the scions firmly and wax heavily and securely all wounds made in the operation, especial care being exercised to press the wax in firmly and neatly about the points of union of scions with the body of the tree. The sectional drawing will show more clearly than printed description the manner of making the "bridge."

RECEIPT FOR STANDARD GRAFTING WAX

Melt together four parts (by weight) of resin, two parts of bees-wax and one part of tallow. Pour the mixture into a pail or tub of cold water. As the mass begins to cool so that it can be handled, grease the hands with tallow and pull and work the lump of wax until it becomes quite light in color. Form into small balls or sticks for convenient use. This wax will keep in good condition indefinitely.

BULLETIN

OF THE

Ohio Agricultural Experiment Station

NUMBER 209.

AUGUST, 1909.

RATIONS FOR FATTENING SWINE.

By B. E. CARMICHAEL.

FEEDS FOR USE WITH CORN.

A number of experiments in pork production have been conducted by this Station to determine the efficiency of different rations, all of them made up in part, at least, of corn. While much more work in this direction is needed, yet it is believed that the results as secured to date may indicate ways by which the profits (too often very meager, if not entirely wanting) from pork production may be increased. It is an accepted fact that corn alone will not produce the most rapid nor, under market conditions approximating the conditions that exist at present, most economical gains with growing, fattening swine. There may have been market conditions under which the use of corn alone would yield a maximum profit, but such conditions do not now prevail. An intelligent use of feeds is necessary, even with the present high price of pork, if the fattening of swine is to prove profitable. On the other hand, even at present prices, corn may well be used extensively in pork production, if properly combined with other feeds; indeed, no other grain feed of equal abundance and efficiency in the production of pork is so cheap as corn.

Results obtained from a few of the many useful combinations in which corn may be used are given on the following pages. An attempt has been made to classify the results in such a way as to afford fair comparisons of the various rations. The reader is urged to study efficiency of rations, rather than cash profits, for profits vary as market conditions fluctuate. Efficiency of rations does not change with varying market conditions, but profits that

result from the use of rations of equal efficiency, pound for pound, in producing gains in live weight, do vary greatly on account of widely varying market prices of the feeds which constitute the rations. It is, then, obviously impossible to suggest a ration that will prove most profitable under all conditions. Results of feeding tests will show the efficiency of rations, but feeders will need to apply local market conditions to these results in order to select the ration that will give best financial returns.

In studying the efficiency of various rations care should be taken to compare only the results of experiments that were conducted simultaneously, as factors other than feed may cause wide differences in results secured from experiments that were conducted under conditions that were not identical in all respects except the rations used.

In all of these experiments, young, growing swine were used. It is entirely probable that the results obtained will not prove strictly applicable to the fattening of mature, thin swine. However, relatively few mature hogs are fattened nowadays, and the results secured will apply to most of the swine feeding operations as now carried on.

Corn was ground before being fed, except in the experiments with hogs in cattle feed-lots, when shelled corn was used. Ground feeds were mixed together and fed with sufficient water to form a thick slop. Daily rations were supplied in two equal portions. A mixture of salt and ashes was regularly kept before the swine during all experiments. All proportions indicated in the description of rations refer to the parts, by weight, of the different feeds used in the rations.

GRAIN RATIONS FOR FEEDING IN DRY LOTS.

Table I shows the results of an experiment covering 66 days in which four different supplements for corn were used, viz: soy-bean meal, wheat middlings, digester tankage and skim milk. While much more work will need to be done before definite figures representing the relative values of these feeds for supplementing corn may be secured, yet the table sets forth a number of facts that are useful in deciding what feeds to use in connection with corn, which will doubtless continue to be the chief grain used for fattening swine in dry lots.

Of the feeds used in connection with corn, skim milk gave the highest daily gain per pig. Wherever skim milk is available for pig feeding, it seems very improbable that any other feed

will supplement corn more completely, or that any ration will produce any more rapid and economical gains than will corn and skim milk. The chief difficulty with this ration is the fact that skim milk is not available for extensive use in the greater hog-producing sections. Nevertheless, wherever it is available, skim milk and corn will doubtless prove as efficient a ration as can be used for fattening swine. The rate of gain for the lot fed corn and skim milk was high—over two pounds daily per pig.

TABLE I: GRAIN RATIONS FOR FEEDING IN DRY LOTS.

6 Hogs in Each Lot. Experiment I, lasting 66 Days. February 13 to April 19, 1907.

Ration	Initial weight	Final weight	Gain	Average daily gain per pig	Total feed consumed	Average daily feed consumed per pig	Feed consumed per 100 lbs. gain
Corn meal, ...	Lbs. 534	Lbs. 743	Lbs. 209*	Lbs. .571	Lbs. 1291	Lbs. 3.53	Lbs. 617.7
Corn meal, 4;.. Soybean meal, 1	533	959	426	1.075	1823	4.60	427.9
Corn meal, 1;.. Middlings, 1 ..	583.5	1078.5	495	1.250	2087	5.27	421.6
Corn meal, 6;.. Tankage, 1, ...	556.5	1195	638.5	1.612	2300	5.80	360.2
Corn meal, 1;.. Skim milk, 2.77	628.5	1199	684**	2.023	1983 corn 5505 s.m.	5.86 16.28	289.9 804.8

* One hog taken out March 20.

**One hog taken out February 21.

Digester tankage, a packing house by-product, ranked next to skim milk for efficiency in producing rapid and, from the standpoint of feed consumed for a pound of gain produced, economical gains. The amount of feed required to produce one hundred pounds of gain was comparatively small—360.2 pounds. The large amount of corn consumed daily per pig by the corn and tankage and the corn and skim milk lots is worthy of note. When either of these feeds was used, a much larger amount of corn was consumed daily than when a ration of corn alone, corn and middlings or corn and soybean meal was fed.

The lot which received corn and middlings, equal parts of each by weight, made fair gains and at a not exceedingly heavy expenditure of feed. The amount of feed consumed was much lower than for the corn and skim milk lot or the corn and tankage lot, and the amount of feed required for a given gain was relatively large. The relatively low consumption of corn is especially striking.

The lot which received a ration of corn, 4 parts; soybean meal, 1 part, failed to consume a sufficient amount of feed to produce very rapid gains. The low consumption of feed was due to the fact that the pigs did not relish the soybean meal and corn meal mixture. No pig in this lot gained more than 1.4 pounds daily. In later experiments at this Station corn and soybeans gave excellent results. (See page 76.)

When the results that were yielded by the lot fed corn alone are considered, it is not difficult to understand why many farmers find that hog feeding is not so profitable as it should be. The amount of feed consumed by this lot was small, the rate of gain was very low, and the amount of feed required to produce one pound of gain was very high as compared with any of the other four lots.

TABLE II: AMOUNT* OF PORK PRODUCED BY ONE BUSHEL OF CORN OR ITS EQUIVALENT. EXPERIMENT I.

Ration	Corn meal	Cornmeal, 1; Middlings, 1	** Corn meal, 4; Soybean meal, 1	Cornmeal, 6; Tankage, 1	Cornmeal, 1; Skim milk, 2.7
Pork produced by 100 pounds of feed, lbs.	16.19	23.71	23.35	27.76	9.13
Cost of 100 pounds feed	\$1.00	\$1.125	\$1.10	\$1.14	\$.37
Amount of feed purchasable for 56 cts., (the value of a bushel of corn,) lbs..	56.0	49.7	50.9	49.0	149.2
Pounds of pork produced from feed equal in cost to one bushel of corn.	9.0	11.8	11.9	13.6	13.6

*Corn, 56 cents per bushel; middlings, \$25.00 per ton; tankage, \$40.00 per ton; skim milk, \$3.00 per ton.

**See page 76 for result of second test of soybean meal.

It will be noted that a bushel of corn, as fed to Lot 1, produced only 9 pounds of gain. Had a portion of this corn been sold at 56 cents per bushel and the proceeds used to purchase supplemental feeds at the following prices: middlings, \$25 per ton; soybeans, \$30 per ton; tankage, \$40 per ton; skim milk, \$3 per ton, the amount of gain produced from one bushel of corn or its equivalent would have been 11.8, 11.9, 13.6 and 13.6 pounds respectively, as is shown in Table II. In other words, a given amount of money invested in corn and tankage or in corn and skim milk would have produced one half more gains than if invested in corn alone; and a much shorter time would have been required for this increased production. At the prices named, digester tankage and skim milk

would be equally efficient so far as amount of pork produced from a bushel of corn is concerned, but the rate of production was higher with corn and skim milk than with corn and tankage. Market prices vary greatly from time to time, and the above comparison is accurate only for the prices named.

TABLE III: COST PER 100 POUNDS PORK PRODUCED. EXPERIMENT I.

Price of corn per bushel	Corn alone	Cornmeal, 4;* Soybean meal, 1. (soybeans at \$30 per ton.)	Cornmeal, 6; Tankage, 1. (tankage at \$40 per ton.)	Cornmeal, 1; Middlings, 1. (middlings at \$28 per ton.)	Cornmeal, 1; Skim milk, 2.77. (skim milk at \$3 per ton.)
\$.28	\$3.09	\$3.00	\$2.57	\$4.01	\$2.66
.35	3.86	3.42	2.96	4.27	3.02
.42	4.63	3.85	3.34	4.53	3.38
.49	5.40	4.28	3.73	4.80	3.74
.56	6.18	4.71	4.12	5.06	4.11
.63	6.95	5.14	4.50	5.32	4.47
.70	7.72	5.56	4.89	5.59	4.83
.77	8.49	5.99	5.27	5.85	5.19
.84	9.26	6.42	5.66	6.11	5.56

*See below for the results of a second test of soybean meal

Table III shows the cost of one hundred pounds of pork as produced in this test, with various prices for corn. The price of feeds other than corn would, of course, also have an important bearing on the cost of pork. The table is not presented with the thought that it will apply strictly to every case, but, rather, to show the great importance of considering cost of feeds as well as efficiency.

SOYBEANS COMPARED WITH TANKAGE FOR SUPPLEMENTING CORN IN DRY LOT FEEDING.

In two tests to compare soybeans and tankage as supplements for corn in dry lot feeding, the results shown in Table IV were secured. The advantage of both the corn and soybean and the corn and tankage rations over the ration of corn alone is very evident. It will be observed that soybeans made a much better showing in these tests than in a former one. No reason was apparent for the marked dislike which the pigs that received soybeans in the previous test showed for the corn and soybean mixture. While the experiments conducted at this Station indicate that pigs are not so fond of soybeans as of some other feeds, notably skim milk and tankage, yet the results of these two tests show an especially high value for soybeans as a supplement for corn.

TABLE IV: GRAIN RATIONS FOR FEEDING IN DRY LOTS.

5 Hogs* in Each Lot.—Experiment II lasting 84 Days. November 24, '08 to February 15, '09.

Ration	Initial weight	Final weight	Gain	Average daily gain per pig	Feed consumed	Average daily feed consumed per pig	Feed consumed per 100 lbs. gain
Cornmeal.....	Lbs. 653.5	Lbs. 1074.5	Lbs. 421	Lbs. 1.002	Lbs. 2336.5	Lbs. 5.56	Lbs. 554.9
Cornmeal, 8;.... Tankage, 1.....	657	1363.5	706.5	1.632	2784	6.62	394.1
Cornmeal 4;.... Soybean meal, 1.	520.5	1063.5	543	1.616	2163.5	6.44	398.4

6 hogs in each lot—Experiment III. lasting 56 days. December 22, '08 to February 15, '09

Cornmeal, 8;.... Tankage, 1.....	843	1333	490	1.458	2145	6.38	437.7
Cornmeal, 4;.... Soybean meal, 1	846	1331	485	1.443	2103	6.25	433.6

*Only four hogs in lot fed corn and soybeans.

The corn, soybeans and tankage as used in this experiment were sampled and analyzed under the direction of Mr. J. W. Ames, Chemist of this Station, with the results as shown in Table V.

TABLE V: PERCENTAGE COMPOSITION OF FEEDS.

	Water	Ash	Protein	Fiber	Nitrogen-free Extract	Ether Extract
Corn.....	15.50	1.21	8.90	1.99	68.74	3.66
Soybeans.....	11.84	4.86	38.62	1.91	25.56	17.21
Tankage.....	7.81	14.06	59.24	3.59	2.73	12.57

Table VI shows the average amount of the different food constituents consumed daily per pig throughout the experiment. It will be noted that the ration of corn alone contained a very small amount of ash and of protein as compared with the rations that contain either soybean meal or tankage in connection with corn.

Feeds for use in connection with corn should be relatively higher in protein and ash than is corn, so as to make up the marked deficiency of corn in these materials and thus provide for the growth of bone and muscle as well as for the formation of fat.

TABLE VI: FOOD CONSTITUENTS IN CONCENTRATES
CONSUMED DAILY PER HOG.

Ration	Ash	Protein	Fiber	Nitrogen-free Extract	Ether Extract
Experiment II					
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Cornmeal.....	.067	.495	.110	3 824	.203
Cornmeal, 8;.....	.071	.524	.117	4 051	.216
Tankage, 1.....	.103	.436	.026	0 200	.092
Total.....	.174	.960	.143	4 071	.308
Cornmeal, 4;.....	.062	.458	.103	3 540	.188
Soybean meal, 1.....	.062	.497	.024	.330	.222
Total.....	.124	.955	.127	3 870	.410
Experiment III.					
Cornmeal, 8;.....	.068	.505	.113	3 900	.207
Tankage, 1.....	.100	.420	.025	.019	.089
Total.....	.168	.925	.138	3 919	.296
Cornmeal, 4;.....	.060	.445	.099	3 441	.183
Soybean meal, 1.....	.061	.483	.024	.319	.215
Total.....	.121	.928	.123	3 760	.398

Table VII shows the warm dressed weights of the various lots. This information was kindly furnished by Messrs. Swift and Company who slaughtered the various lots at their Chicago house February 25. The home weights were taken February 22, some days after the close of the experiment, but while the hogs were receiving the same rations as were fed during the experiment. There is need for more evidence concerning the dressed percentages of swine fed on these rations before any definite conclusions on this point will be justified. The lighter dressed percentages of the two lots fed for 56 days is largely, if not wholly, explained by the lighter average live weight of these lots.

TABLE VII: DRESSED PERCENTAGES.

5 hogs in each lot.—Experiment II lasting 84 days. November 24, '08 to February 15, '09,

Ration	Weight at Wooster February 22	Warm dressed weight at Chicago, Feb. 25	Dressed percentages (warm)
Cornmeal.....	Lbs. 1115.5	Lbs. 893	% 80.05
Cornmeal, 8; Tankage, 1.....	1421	1168	82.19
Cornmeal, 4*; Soybean meal, 1.....	1109	896	80.79

6 hogs in each lot.—Experiment III lasting 56 days. December 22, '08 to February 15, '09.

Cornmeal, 8; Tankage, 1.....	1419.5	1126	79.32
Cornmeal, 4; Soybean meal, 1.....	1417.5	1099	77.53

*Only four hogs in lot fed cornmeal and soybean meal.

Table VIII, based on the results that were secured from the lots that were fed 84 days, shows the cost of one hundred pounds of pork under market prices for corn ranging from 28 to 84 cents per bushel, with soybeans at \$30 per ton and tankage at \$40 per ton.

TABLE VIII: COST PER 100 POUNDS GAIN.

Experiment II lasting 84 days, November 24, '08 to February 15, '09.

Price of corn per bushel	Corn alone	Cornmeal, 8; Tankage, 1 (tankage @ \$40 per ton)	Cornmeal, 4; Soybean meal, 1 (soybeans @ \$30 per ton.)
\$.28	\$2.77	\$2.63	\$2.79
.35	3.47	3.07	3.19
.42	4.16	3.50	3.59
.49	4.86	3.94	3.98
.56	5.55	4.38	4.38
.63	6.24	4.82	4.78
.70	6.94	5.25	5.18
.77	7.63	5.69	5.58
.84	8.32	6.13	5.98

Soybeans are not usually available for use at \$30 per ton, but their cost of production would indicate that they may possibly soon be available at about this price. It will be noted that the financial advantage is not always with the same lot. With very cheap corn, it alone may be more profitable to use than the other rations. Using

the results secured from the three lots that were fed the rations indicated for 84 days as the basis of calculations, the corn and soybean ration would have produced the most costly gains with corn at 28 cents per bushel, and the cheapest gains with corn at only slightly above 56 cents per bushel. This table emphasizes again the importance of a knowledge concerning both efficiency and cost of rations; without such knowledge feeders cannot hope to secure best results from their feeding operations.

Although present prices for soybeans that are fit for seed prohibit their profitable use for feeding purposes, yet, with its high feeding value, effect as a soil improver, and an average yield under Ohio conditions of about 18 bushels (1080 pounds) per acre, it seems entirely probable that the soybean crop may come to be grown very extensively in Ohio for feed purposes. Besides the matter of feeding value, the effect of the soybean plant as a soil improver is worthy of careful consideration. For information relative to general characteristics, culture, etc., of the soybean, the reader is referred to Circular 78 of this Station.

Farm grown feeds have been found to be very efficient supplements for corn, but it is often better business practice to sell a part of the farm products and buy commercial feeds, rather than to feed a ration all of which has been grown on the farm. The example of soybeans is a case of this kind. At present prices—at least \$2.00 per bushel, wholesale—soybeans could well be sold, and the proceeds used to buy such commercial feeds as would prove more profitable than soybeans to use with corn for fattening swine under present market conditions. Beans that have been cracked in threshing or that have been rendered unmarketable in any other way that does not impair their feeding value could be used very profitably in pork production.

CORN AND BLUEGRASS PASTURE COMPARED WITH CORN, SKIM MILK AND BLUE GRASS PASTURE.

Two lots of pigs, five in each lot, were fed rations as above. The results of this test are given in Table IX. Each lot received (for Lot 1) all of the corn or (for Lot 2) corn and skim milk that they would consume. The pigs were about four months old when the test began, July 6. Both lots were fed until September 22, 1906, when the pigs from Lot 2 were sold. Lot 1, fed corn and bluegrass pasture, was fed until their total gain was approximately equal to that of Lot 2. The rate of gain was more than one half greater with Lot 2 than with Lot 1.

TABLE IX: CORN AND BLUEGRASS PASTURE COMPARED WITH CORN, SKIM MILK AND BLUEGRASS PASTURE.

5 pigs in each lot—Experiment IV lasting 79 days. July 5 to September 20, '06

Grain ration	Initial weight	Final weight	Gain	Average daily gain per pig	Feed consumed	Feed consumed per 100 lbs. gain
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Corn.....	349	780	431	1.091	1644.5	381.5
Corn and skim milk.....	384	1028	644	1.630	1697.5 5647	263.5 corn 876.8 s.m.

It should be stated that in this, as in all other similar tests conducted at this Station, the hogs to which corn alone was fed ate very much more grass than did the hogs which received corn and skim milk. Besides the lower rate of gain made by Lot 1, this lot after having made practically the same total gain (640 lbs.) that Lot 2 made, would have sold on the market for 25 cents per hundred-weight less. This point is often of great importance, but market conditions are so irregular that no attempt will be made here to advise feeders when to market their product. This matter must be decided by the feeder after considering the conditions which exist during each year. However, it can be said that economy and rapidity of gains seldom prevent advantageous marketing.

DRY LOT VS. PASTURE.

Experiments conducted during the summers of 1907 and 1908 give an excellent opportunity to compare dry lot feeding with feeding on pasture, when corn alone, or corn and tankage are used. These experiments are summarized in Table X. It will be noted that in both years the use of pasture added materially to the rate and economy of gain when corn alone was fed. In the 1907 test corn and tankage in dry lot produced almost as great and, so far as concentrates are concerned, economical gain as did corn, tankage and pasture. In the 1908 test, with younger, smaller pigs, quite an appreciable difference in rate and economy of gain is noted, in favor of the pasture lot, even when corn and tankage were fed. Pasture grass is usually a relatively cheap feed and should be used extensively for pork production, especially when grain feeds are high in price. Green feeds other than bluegrass may often be used to good advantage; among them are clover, alfalfa, timothy and rape. In both of the experiments summarized in Table X heavy grain rations were used.

TABLE X: DRY LOT VS. PASTURE.

5 hogs in each lot—Experiment V lasting 55 days. July 5 to August 28, '07.

Ration	Initial weight	Final weight	Gain	Average daily gain per pig	Feed consumed	Feed consumed per 100 lbs. gain
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Cornmeal on pasture.....	719.5	1103.5	384	1.396	1795	467.4
Cornmeal in dry lot.....	709.5	940	230.5	.838	1370.5	594.5
Cornmeal, 6; tankage, 1, on pasture.....	699.5	1246.5	547	1.989	2084	380.9
Cornmeal, 6; tankage, 1, in dry lot.....	719	1246	527	1.916	2051.5	389.2

5 hogs in each lot—Experiment VI lasting 62 days. June 26 to August 26, '08

Cornmeal on pasture.....	324.5	696	371.5	1.198	1279.5	344.4
Cornmeal in dry lot.....	338.5	547.5	209	.674	1062.5	508.3
Cornmeal, 8; tankage, 1 on pasture.....	329	831	502	1.619	1613	321.3
Cornmeal, 8; tankage, 1 in dry lot.....	335.5	826.5	488	1.574	1697.5	347.8

The financial results that would have been secured under varying market conditions, using the 1908 test as the basis of calculations are shown in Table XI. It will be noted that the cheaper the corn the less the relative profit from pasturing in connection with both the corn and the corn and tankage lots. In this calculation a fixed charge—\$1.00 for the corn and tankage lot and \$1.50 for the corn lot—is made for pasture. The reason for this difference in charge for pasture is the fact, noted above, that the corn lot consumed noticeably more grass than did the corn and tankage lot.

From the foregoing it is seen that pasture may often be a source of very valuable feed. An extensive use of pasture should often be made in pork production, especially when grain is very high in price. In this connection attention is directed to the data presented in Table XIV, page 84, which shows the results secured from the use of light and heavy grain rations upon pasture. The amount of corn required for one hundred pounds gain is 467.4 pounds for the lot fed a heavy corn ration upon pasture and only 386.7 pounds for the lot which received a light grain ration. In this experiment the light grain ration was equal in amount to two-thirds of the heavy grain ration.

TABLE XI: FINANCIAL RESULTS UNDER VARYING MARKET CONDITIONS.

Experiment VI lasting 62 days. June 26 to August 26, '08.

Rations	Corn meal in dry lot	Corn meal on pasture	Corn meal and tankage on pasture	Corn meal and tankage in dry lot
Corn, 45 cents per bushel; tankage, \$42.60 per ton				
Cost per hundred lbs. gain.....	\$4.09	\$ 3.17	\$ 3.25	\$ 3.31
Profit on gain in live weight of 5 hogs @ 5 cents per lb.....	1.91	6.80	8 76	8.26
Profit on gain in live weight of 5 hogs @ 6 cents per lb.....	4.00	10.51	13.78	13.14
Corn, 60 cents per bushel; tankage, \$42.60 per ton.				
Cost per 100 pounds gain.....	\$ 5.45	\$ 4.09	\$ 4.02	\$ 4.14
Profit on gain in live weight of 5 hogs @ 5 cents per lb.....	loss .93	3.37	4.92	4.22
Profit on gain in live weight of 5 hogs @ 6 cents per lb.....	1.16	7.08	9 34	9.10
Corn, 75 cents per bushel; tankage, \$42.60 per ton,				
Cost per 100 pounds gain.....	\$ 6.81	\$ 5.02	\$ 4.78	\$ 4.96
Profit on gain in live weight of 5 hogs @ 5 cents per lb.....	loss 3.78	loss .06	1.08	.17
Profit on gain in live weight of 5 hogs @ 6 cents per lb.....	loss 1.69	3.65	6.10	5.05

FEEDING ON BLUEGRASS PASTURE. CORN COMPARED WITH CORN AND TANKAGE. TWO TESTS.

In 1907 and in 1908 tests were conducted to compare corn with corn and tankage for feeding on pasture. The pasture used in these tests, as in the one just discussed, consisted of bluegrass and white clover. In 1907 the corn and tankage mixture consisted of 6 parts cornmeal to 1 part tankage, by weight; in 1908 the proportions were 8 to 1, for cornmeal and tankage, respectively. In both tests the hogs were fed all the grain they would consume. Table XII shows the results secured from these tests.

In each case the lot that received corn and tankage made greater gains than were secured from the use of corn alone. Less concentrates were required for a given gain when corn and tankage were fed than when only corn was given. Moreover, as was stated in connection with the comparison of corn with corn and skim milk on pasture, the lot fed corn alone consumed more grass than did the other lots. With corn very low in price it is possible that corn alone on pasture would produce more net profit than would corn and a supplemental feed. On this account, the feeder should know what results are to be expected from various rations so that he may apply local market conditions to these results.

TABLE XII: CORNMEAL COMPARED WITH CORNMEAL AND TANKAGE ON BLUEGRASS PASTURE.

Five hogs in each lot. Experiment VII lasting 55 days. July 5th to August 28th, 1907.

Grain ration	Initial weight	Final weight	Gain	Average daily gain per pig	Feed consumed	Feed consumed per 100 pounds gain
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Cornmeal, 6; tankage, 1.....	699.5	1246.5	547	1.989	2084	380.9
Cornmeal.....	719.5	1103.5	384	1.396	1795	467.4

Five hogs in each lot. Experiment VIII lasting 62 days. June 26th to August 26th, 1908.

Cornmeal, 8; tankage, 1	329	831	502	1.619	1613	321.3
Cornmeal.....	324.5	696	371.5	1.198	1279.5	344.4

LIGHT VS. HEAVY GRAIN RATIONS IN DRY LOT.

Two experiments have been conducted to compare light and heavy rations, when swine are confined in dry lot. The results of these experiments are presented in table XIII. In these experiments the light ration was equal in amount to three-fourths of the heavy ration. It will be noted that no marked difference in economy of gain resulted—in fact, the amount of feed consumed for a given gain was almost exactly the same for the two different lots.

TABLE XIII: LIGHT VS. HEAVY GRAIN RATIONS IN DRY LOT.

Four hogs in each lot. Experiment IX lasting 198 days, September 19, 1907 to April 3, 1908.

	Ration	Initial weight	Final weight	Gain	Average daily gain per pig	Feed consumed		Feed consumed per 100 lbs. gain	
						Milk	Concentrates	Milk	Concentrates
Sept. 19, 1907, to	Cornmeal, middlings, skim milk	Lbs. 190	Lbs. 557	Lbs. 367	Lbs. 1.277	Lbs. 1444	Lbs. 950	Lbs. 393.4	Lbs. 258.8
Nov. 29, 1907	Cornmeal, middlings, skim milk (¾ full feed),	183	463	280	.972	1083	712.5	386.8	254.5
Nov. 30, 1907, to	Cornmeal 8; tankage 1	557	1457	900	1.785		3834		426.
April 3, 1908	Cornmeal 8; tankage 1 (¾ full feed).....	463	1122	659	1.307		2875.5		436.3

Five hogs in each lot. Experiment X lasting 62 days. June 26th to August 26th, 1908.

	Cornmeal 8; tankage 1	338.5	826.5	488	1.574		1697.5		347.8
	Cornmeal 8; tankage 1 (¾ full feed).....	327	689	362	1.167		1273		352.

The amount of gain was quite widely different—practically one-third more for the heavy-fed lot than for the light-fed lot. These results show that, so far as economy of gain is concerned, no material difference existed between light and heavy feeding as practiced in these tests. In rate of production and, therefore, in length of time required to produce a given amount of pork, a wide difference existed. There seems to be little reason for feeding less than a full ration to swine that are being fattened in dry lot.

The figures presented in the first part of Table XIII show something of the great capacity of swine for converting feed into meat. With the four head which were fed full rations it is seen that during the 198 days of the experiment they gained a total of 1267 pounds in live weight, consuming during this period 4087 pounds of cornmeal, 271 pounds of middlings, 426 pounds of tankage and 1444 pounds of skim milk.

LIGHT VS. HEAVY GRAIN RATIONS ON PASTURE.

With hogs upon pasture the proposition is very different from dry lot feeding, and it is often possible, by feeding relatively light grain rations, to induce hogs to eat a much larger amount of grass than when heavier grain rations are supplied, and thus effect a marked economy in production.

TABLE XIV: LIGHT VS. HEAVY GRAIN RATIONS ON PASTURE.

Five hogs in each lot. Experiment XI lasting 55 days. July 5th to August 28th 1907.

Grain ration	Initial weight	Final weight	Gain	Av. daily gain per pig	Grain consumed	Grain consumed per 100 lbs. gain
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Cornmeal.....	719.5	1103.5	384	1.396	1795	467.4
Cornmeal (¾ full feed)	675	982.5	307.5	1.118	1189.2	386.7

One experiment has been conducted at this Station to compare light and heavy grain rations for hogs on pasture. In this test two lots of pigs, five in each lot, were fed for 55 days upon a grain ration of corn alone with bluegrass and white clover pasture in abundance. The results of this experiment are given in Table XIV, and show that a marked lessening in amount of grain feed required for a pound of gain resulted from withholding a part of the grain, on account of the more extensive use made of a cheaper feed, pasture grass. It is not possible to ascertain the definite amount of grass consumed by the two lots; it was certain, however, that the lot which received the light grain ration consumed more grass than did the lot fed the heavy grain ration.

HOGS IN CATTLE FEED-LOTS.

It is generally considered by feeders that hogs in cattle feed-lots, depending very largely, or exclusively, upon the corn in the droppings from the steers will make as great gains as hogs can be expected to make. A number of tests conducted at this Station showed decided increase in rate of gain when a supplemental feed was used. Facilities for making these tests have been rather limited, on account of the small number of cattle that have been fattened here under conditions that would permit such tests. Consequently, only one supplemental feed, digester tankage, has been used.

These tests were conducted in conjunction with a steer feeding experiment, the plan of which is given below. Later experiments were conducted under similar conditions. The plan of the first test was as follows:

Four lots of steers, seven head in each lot, were fed upon two different rations—two lots upon each ration. Lots 1 and 3 received shelled corn, cottonseed meal, corn stover, mixed hay and corn silage. Lots 2 and 4 received shelled corn, cottonseed meal, corn stover and hay. The two lots last mentioned received more corn and more dry roughage than did the lots first mentioned, on account of not receiving silage, which, of course, contained both grain and roughage. All lots of cattle received the same amount of cottonseed meal daily per steer.

TABLE XV: HOGS FOLLOWING STEERS.

Three hogs in each lot. Experiment XII lasting 63 days, March 20* to May 21, 1907.

Lot	Steer ration	Hog ration	Initial weight	Final weight	Total gain	Average daily gain per pig
1	Silage	Grain from droppings and one-third pound tankage daily per hog in addition	Lbs. 290	Lbs. 565	Lbs. 275	Lbs. 1.46
3	Silage	Grain from droppings.....	280	434	154	.81
4	Dry	Grain from droppings.....	305	530	225	1.19
6	Dry	Grain from droppings and one-third pound tankage daily per hog in addition.....	331	655	324	1.71

Four hogs in each lot. Experiment XIII lasting 56 days, May 22 to July 16, 1907, inclusive.

1	Silage	Grain from droppings and one-third pound tankage daily per hog in addition	445	766	321	1.43
3	Silage	Grain from droppings.....	460	657	197	.88
4	Dry	Grain from droppings.....	470	692	222	.99
6	Dry	Grain from droppings and one-third pound tankage daily per hog in addition.....	445	755	310	1.38

Total gains of lots fed tankage..... 1230 pounds.
 Total gains of lots not fed tankage..... 798 pounds.
 Increased gains by lots fed tankage..... 432 pounds.

* Weight of hogs taken March 20th; feeding of tankage began March 21st.

During the first part of the experiment three hogs were put with each lot of seven cattle; later these hogs were replaced by a thinner lot and four hogs were placed with each lot. The first set of hogs was under experiment for 63 days, the second lot for 56 days.

No corn was fed to the hogs, and, as the cattle feed racks were so constructed as to prevent the grain being thrown out, the hogs secured no grain except that which appeared in the droppings from the steers. All lots were kept supplied with a mixture of ashes and salt. It is of interest to note that the lots fed tankage cared less for the ashes and salt than did the other lots. The tankage was fed at the rate of one-third of a pound daily per pig, in the form of a thin slop. It may be very conveniently fed in this manner and was greatly relished by the hogs, in fact, they exhibited an almost ravenous appetite for it.

Table XV shows the results secured from experiments during which the corn in the steers' droppings was the only grain to which the hogs had access. It will be observed that greatly increased gains resulted from the use of the supplemental feed. There was no way of measuring the exact cost of gains with the different lots, as the amount of corn that passed through the steers might have varied materially. However, there is abundant evidence to show that the use of tankage was very profitable. The two lots that were fed tankage ate 295.5 pounds of this material and made 432 pounds greater gains than did the two lots which were subjected to similar treatment with the exception of the use of tankage. All of the lots left a small amount of corn in the manure, and it cannot be said for a certainty that the tankage fed lots did not eat more corn than did the others.

TABLE XVI: HOGS FOLLOWING STEERS,

Five hogs in each lot. Experiment XIV lasting 71 days. Jan. 15, to March 25, 1908.

Steer ration	Hog ration	Corn fed	Tank-age fed	Initial weight	Final weight	Gain	Av. daily gain per pig.
Silage	Grain from droppings, corn and tankage	Lbs 962.5	Lbs. 121.15	Lbs. 548	Lbs. 1030	Lbs. 482	Lbs. 1.357
Dry	Grain from droppings, corn and tankage	662.5	121.15	553	1000	447	1.259
Silage	Grain from droppings and corn.....	916.5		537	875	338	.952
Dry	Grain from droppings and corn.....	659.3		547	*755	348	1.017

Total gain of lots fed tankage..... 929 pounds
 Total gain of lots not fed tankage..... 686 pounds
 Increased gains by lots fed tankage..... 243 pounds

*One hog taken out March 14, weight 140 pounds.

In tests conducted later than the ones reported above, dry shelled corn was fed in addition to that which was present in the steers' droppings. Tables XVI and XVII show the results of these tests, which are in close agreement with the ones previously discussed. In the tests summarized in Table XVII, tankage was used, but in different amounts, one-half of the lots receiving one-third of a pound of tankage daily per pig, the other half receiving twice as much.

TABLE XVII: COMPARISON OF DIFFERENT AMOUNTS OF TANKAGE
FOR HOGS FOLLOWING STEERS.

Five hogs in each lot. Experiment XV lasting 70 days. January 14th to March 24th, 1909.

Steer ration	Initial weight	Final weight	Gain	Av. daily gain per pig	* Corn consumed during experiment	Tankage consumed during experiment
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Silage	517	960	443	1.265	619	175
Dry.....	530	1040	510	1.457	415	175
Silage	543	1110	567	1.620	650	262.5
Dry	567	1210	643	1.837	549	262.5

Six hogs in each lot. Experiment XVI lasting 70 days. March 25th to June 2nd, 1909.

ilage	625	1107	482	1.147	433	213
Dry.....	620	1099	479	1.140	293	213
Silage	625	1163	538	1.280	433	319.5
Dry	625	1103	478	1.138	293	319.5

Six hogs in each lot. Experiment XVII lasting 69 days. March 26th to June 3rd, 1908

Silage.	595	1200	605	1.461	896	274
Dry	590	1155	565	1.364	723	274
Silage	590	1045	455	1.099	873	137
Dry	1470	4720	375	1.179	671.5	105.2

Total gains of heavy fed tankage lots..... 1170 pounds.

Total gains of light fed tankage lots..... 830 pounds.

Increased gains by heavy fed tankage lots..... 340 pounds.

* Besides that secured from droppings of steers.

† Only five hogs to begin with.

‡ One hog taken out May 7th, weight 125 pounds.

These three experiments conducted to secure data in regard to the amount of tankage which should be fed to hogs in cattle feed lots for best results have shown greater gains, on the whole, from two-thirds of a pound of tankage daily per pig than from only one-third of a pound daily. It will be observed that two of the three tests show better results from the use of the larger amount of tankage. It is expected that further work along this line will be done in connection with future cattle feeding experiments. If other supplemental feeds, suitable for use with corn are more readily available for use than tankage, there is no reason why they should not be used. As has been suggested before, the feed that will produce the desired results at the least cost should be used; to decide this point, market conditions will need to be carefully considered.

SUMMARY.

Corn alone, at prices approximating those that now prevail, is not a profitable ration to use in pork production.

Feeds richer in protein and mineral constituents should be supplied to supplement corn in a way to provide for the growth of muscle and bone as well as for the production of fat.

The use of supplemental feeds of the character mentioned in the preceding paragraph has given good results for feeding in ordinary dry lots, in cattle feed-lots and on pasture.

Skim milk, soybeans, tankage, middlings and pasture grass all proved valuable feeds for use in connection with corn. The supplemental feed to use will depend very largely upon market prices.

In the comparison of light and heavy grain rations for dry lot feeding no marked advantage of either was evident so far as economy of gains was concerned. As would be expected, the heavy grain ration produced more rapid gains than did the light grain rations.

Marked economy in cost of gains resulted from the use of a light grain ration in place of a heavy grain ration for swine on pasture. If a cheaper feed may be used in place of the grain, it is often possible to lessen very materially the cost of pork production by feeding a light grain ration. If concentrates are to be used exclusively, the use of a heavy grain ration would be advisable, unless the aim of the feeder is to hold the stock in a low or moderate condition in order to secure cheaper feeds for fattening later.

It is important for feeders to understand market conditions as well as efficiency of feeds. The rations that produce the most rapid gains are not necessarily the most profitable feeds to use. On the other hand, rations that produce cheap gains may produce these gains so slowly that the profits will be very small.

Either home grown or commercial supplemental feeds may be used in connection with corn to good advantage, and feeders should be ready to use whichever will be most profitable. It will often pay to exchange farm grown feeds for commercial feeds. On the other hand, it is often true that the use of feeds grown on the farm will prove more profitable than the use of commercial feeds.

Feeds other than those discussed in this bulletin have given good results when used to supplement corn. Buttermilk, meat meal, linseed oilmeal, clover, alfalfa and various other feeds may often be fed with corn to good advantage. Whatever feeds are used in pork production, the feeder should pay close attention to market prices of the various feeds that may be had, and use the most economical, efficient feeds that are available.



BULLETIN

OF THE

Ohio Agricultural Experiment Station

NUMBER 210.

OCTOBER, 1909.

THE BLADE BLIGHT OF OATS—A BACTERIAL DISEASE.

By THOS. F. MANNS.

INTRODUCTION.

During the past three seasons the oat crop of Ohio has sustained much loss from a blight disease which has been quite general throughout the Central and Eastern states. From the many inquiries by the farmers of Ohio, and the great differences of opinion among scientific workers, it is quite evident that the nature of the trouble has not been well understood. Many of the farmers supposed the trouble to be of the nature of a rust (See page 98). Among the scientific workers the conclusions reached were widely different. In one section insects¹ were noted as a cause; in another case,² while the origin of the trouble was held to be in doubt, its wide spread development was believed to be due the cold, wet, cloudy season. A third investigator found the disease not to be directly the result of insect work³. Prof. J. Dearness⁴ writing through the Farmer's Advocate, a Canadian paper, in 1907, (after having reviewed the New York State Reports for 1889-1890 by C. H. Peck) supposed the cause to be either bacterial, in the class with the bacterium of pear blight, or else due to the reduction of the vitality of the oats through climatic causes. Prof. Selby, in a report on plant diseases,⁵ supposed the trouble to be due to the great changes of weather, possibly aided by aphides. A similar trouble in 1890 was pronounced by the Division of Plant Pathology, Department of Agriculture, Washington, D. C., to be due to bacteria⁶. In Connecticut a similar disease was supposed to be

¹Special Bulletin No. 38, Michigan Agricultural College, July 1907, R. H. Pettit.

²Press Bulletin No. 286, Ohio Experiment Station, July 15th, 1907, Chas. E. Thorne.

³Journal of Economic Entomology, June 1908, pp. 190 and 191, H. A. Gossard.

⁴Farmer's Advocate, London, Ontario, Vol. XLII, No. 775, Aug. 1, 1907, Prof. J. Dearness.

⁵Ohio Agricultural Report, 1907, p. 891.

⁶Journal of Mycology, Vol. 6, pp. 72-3, 1890, B. T. Galloway and E. A. Southworth.

due to insects⁷. What appears to have been the same disease was prevalent in New York in 1889 and was pronounced by C. H. Peck⁸ as due to a fungus; however, this view was later modified and Prof. Peck pronounced the disease not to be due to fungi, and he further noted that he believed it was not the results of insects or nematode work⁹. In 1906 the Connecticut Station reported an outbreak of a disease somewhat similar to the blight in which they could find no bacteria as an associated cause. "The trouble apparently resulted from unfavorable weather conditions, possibly aggravated by some root disease."¹⁰ Insects many times in the past^{11 12 13} have been assigned as causing blights of oats which appear very similar from descriptions to the severe blight of 1907-8.

CAUSE.

The author finds the disease, as manifested in Ohio, to be caused by a symbiotic relation of two species of bacteria; the disease being greatly influenced by weather conditions and to some extent disseminated by insects.

PREVIOUS LITERATURE ON THIS DISEASE

Very little has been previously written upon this disease, and where studies or notes have been reported the articles are very short; for these reasons the writer quotes very fully from the references noted. The disease as it appeared in 1890 was described by Galloway and Southworth as follows:⁶

"During the months of May and June, 1890, we received repeated complaints and inquiries concerning a mysterious oat disease which then threatened to destroy the entire crop of the Eastern and Central States.

During the month of May, when the oats were from 6 inches to a foot in height, the leaves suddenly began to turn brown and die at the tops. The lower leaves were attacked first and the brown color soon extended their entire length. In a very short time all the leaves were dead or partially brown, and the prospects were that the plants would die and the oat crop be a total failure. About the middle of June, however, the fields began to revive, the oats put out some few fresh, green leaves, most of them headed out, and by the first of July many of the fields appeared in a fair condition on superficial observation. In reality, however, the losses from the disease will amount to from 35 to 75 percent of the crop, according to the locality. Very discouraging losses are reported from the State of Pennsylvania, where there is probably not a healthy oat field to be found. Kentucky and Tennessee have suffered even more, their present averages as reported to the Statistical Division being the lowest ever reported from any state for a staple crop.

⁷13th Annual Report of Connecticut Agricultural Experiment Station, 1889, p. 180. Roland Thaxter.

⁸New York State Report, 1889.

⁹New York State Report, 1890.

¹⁰Report of the Connecticut Agricultural Experiment Station for the year 1906, Part V., p. 316.

¹¹Insect Life, Vol. III, p. 306.

¹²Bulletin 108, Division of Entomology, Agric. Exp't. Sta., Minn., April 1908, F. L. Washburn.

¹³Bulletin 44, United States Department of Agriculture, Division of Entomology, 1904.

⁶Journal of Mycology, Vol. 6, p. 72-3, 1890.

The disease extends from New England to Georgia, and from the Atlantic coast as far west as Indiana and Illinois. It is not present in Michigan. All the agents for the Statistical Division agree in ascribing the cause of this remarkable decline in the oat crop to the same thing, namely, a "blight" or "rust" which struck the fields in May.

The disease prevented the oats from stooling well, and it frequently happened that all the shoots but the main one of a stool were killed. As a result the oats are very thin, and in riding along by a field even at a considerable distance one can see to the ground between the drill rows when the oats are in full head. Besides this the losses are augmented by the fact that the amount of green foliage which developed after the attack, was not sufficient to produce a strong growth of the surviving stalks; nor to supply material for a good-sized head; the straw is therefore short and light and the heads small. The heads do not seem to be well filled, and threshing will probably reveal a lighter yield than farmers themselves expect.

Such a universal disease can be attributed to no deterioration of soil or lack of cultivation, although there is no doubt that good cultivation will produce better oats than poor, even when they are diseased. The disease has attacked oats on the best as well as on the poorest soils, fields that were fertilized as well as those that were not. The oats are best, however, in level well cultivated and drained fields, while they are poorest in low, wet spots and on hillsides and other places where the soil is thin. In such places they are too short to be harvested.

A very careful study of the plants has been made in the field and laboratory, but nothing in the way of a fungous or animal parasite that could cause the trouble has been found. From the nature of the disease our attention has been directed mainly to a study of it from a bacterial standpoint. Bacteria have been found in every specimen examined. Nearly 200 cultures have been made in at least a dozen different media and all have yielded two germs, one of which is exceedingly abundant. In nearly 50 cases the disease has been produced in young pot-grown plants by inoculating from direct material. Inoculations of young plants with pure cultures are now under way and it is hoped that some definite results will soon be obtained from this source.

(Since writing this the disease has been produced in fifty or more cases by inoculating with the more abundant organism. Five days after inoculating, the characteristic discolorations appeared and cultures made from these have yielded the typical organism in a nearly pure condition.)"

There is still a possibility that although the disease may be caused by bacteria they are dependent upon certain conditions of the atmosphere for their development, and need not be feared another year. Experiments to settle this question are also under way.

What appears to have been the same disease was described by Prof. C. H. Peck as occurring in New York in 1889 and the cause was attributed to a fungus, *Fusicladium destruens*. He reported as follows:⁸

"In the southern part of St. Lawrence County, which was visited by the writer the past summer (1889) scarcely a field of oats was free from this disease. So prevalent was it that the general color of the fields was changed thereby, and it was the opinion of the owners that their oats were rusting badly. Upon close examination, no rust was to be found. In its stead, the discoloration of the leaves and the fungus now described appeared. It is apparently a very injurious and destructive fungus."

⁸New York State Report 1889, C. H. Peck.

However, in 1890, Dr. Peck found upon further study of the disease, reason to modify his former conclusions in regard to *Fusicladium* being the cause. He reported as follows:⁹

"When my last report was written, this fungus (*Fusicladium destruens*) was suspected of being the cause of the disease, which has appeared over a wide extent of country, and in the fields examined scarcely an unaffected plant could be found. It is hardly possible that the *Fusicladium* could have spread so extensively in so short a time. It is more reasonable to suppose that it, like the other fungi mentioned, is a consequence rather than a cause of the disease." He noted, however, that the injury appeared not to be the work of insects or nematodes.

The Connecticut Station recognized the blight and reported as follows:⁷

"*Coleothrips 3-fasciata* Fitch: A 'rust' of oats has been the cause of much complaint throughout the State during the past summer, and where examined proved to be due, in most cases, not to the common fungus rusts (*Puccinia coronata* and *P. graminis*); but to a minute insect which Mr. Pergande, of Washington, has kindly determined as probably *Coleothrips 3-fasciata* Fitch. Fields infested by it have a reddish, wilted look and often mature comparatively little of their seed. No remedy can be suggested in this case."

Miss Freda Detmers, botanist of the Ohio Experiment Station for 1890 and '91, mentions a blight of oats due to bacteria upon which she did some work, quoted as follows:¹⁴

"The work of the division during the past year has mainly been confined to a careful study of the fungous diseases of plants. * * * Briefly stated the diseases investigated are as follows:" Among many others is mentioned "an undescribed bacterial disease of oats."

Pettit described the trouble in March 1907 as follows:¹

"From all parts of the state, complaints are coming in with respect to the condition of the oat crop. The last week has seen a notable change in the outlook. The young oats in a large part of the state have suddenly become as if stricken by blight, the outer leaves turning yellow and afterwards reddish until, after a little time, the field appears as if badly rusted. A closer examination shows that there are few if any rust pustules and the appearance on the surface is just enough different from that produced by rust to raise a doubt as to the real cause of the difficulty.

Careful examination with the aid of a powerful lens shows the culprit to be a minute insect called a thrips, very small, and very quick in its movements, jumping like a flea when disturbed and disappearing completely. These little creatures have narrow wings with fringes of long hairs instead of the ordinary form of wings. They scrape the surfaces of the oat leaves and cause them to become withered and to turn yellow and die. Now, this little creature has never been seen in numbers by the writer and it is very difficult to judge just what will be the outcome of the infestation. If one might judge by the behavior of its relatives one would expect the condition to improve after one or two good rains, since thrips, in general, thrive in hot, dry weather, and do not do well when it is moist. However, it seems to be quite serious in places where there has been a fairly good supply of rain. The larger the plants are, the better they fare.

⁹New York State Report, 1890.

¹³Th Annual Report Connecticut Agricultural Experiment Station, 1889, p. 180, Dr. Roland Thaxter.

¹⁴Ohio Experiment Station, in the Annual Report for 1891, p. XXXIV.

¹Michigan Agricultural College, July 1907, Special Bulletin No. 38.

Now, there seems to be nothing one can do to check the trouble at this time. If it were possible to stimulate the growth of the plants in any way it would be a benefit, but such a course seems to be impossible. All plant life seems to be more susceptible to insects when plants are in poor condition for any reason, and the backward, cold, wet spring furnishes a very sufficient reason for the lack of vigor and resisting power which they should have to help repel the invaders."

Director Thorne, of the Ohio Station, reviews the disease² in a press bulletin as follows:

"Reports received by the Ohio Experiment Station indicate a general prevalence over the state of an abnormal condition of oats, shown by many of the blades turning yellow, or reddish yellow, in spots or streaks, and finally dying at the tips or throughout the entire length.

A similar condition was manifested by the oat crop of Ohio and farther west in 1890, followed by a considerable reduction in yield and such a condition is reported by the Connecticut Experiment Station as occurring in that state in 1906.

The attack of 1890 was pronounced by the Division of Vegetable Pathology, U. S. Department of Agriculture, to be due to bacterial infection. The Connecticut Station failed to find evidence of such infection last year, and we have not yet found conclusive evidence of such infection in the present attack.

In the case of the present attack plant lice have been mentioned by many observers as being unusually abundant on oats, but we have not as yet found conclusive evidence as to whether they have or have not, borne an important part in the spread of the trouble. We know of no remedy or prevention.

In all cases similar weather conditions have been observed, namely: excess of cold, rainy weather, followed by hot sunshine, and it appears that these conditions have been the chief factors in producing the outbreak.

In this connection the following extract from the report of this Station for 1890 (it being then located at Columbus) may be of interest:

"The Spring of 1890 was very unfavorable to farming operations throughout the greater portion of Ohio, on account of almost incessant rains. The planting of corn, oats and potatoes was generally delayed, and cultivation was much interfered with until after the middle of June. On the Station farm oats and potatoes were planted late, and both crops suffered so much from blight that not half an average yield was obtained."

Prof. H. A. Gossard in reviewing the insect troubles of 1907 writes as follows:³

"During the spring, wheat and oats over Ohio suffered from a peculiar disease, marked by a reddening, yellowing and browning of the leaves, and a general stunting of the growth and retardation of the development in all respects. From the fact that the grain louse, *Macrosiphum granaria*, was noticed in considerable numbers in some fields, the newspapers and many correspondents attributed the damage to the lice. Others suspected thrips of causing the mischief. After an examination which I deemed adequate, I concluded that neither of these insects was primarily responsible for the disease so far as Ohio was concerned, though both species added to the trouble to a

²Press Bulletin No. 286, Ohio Experiment Station, 1907.

³In the Journal of Economic Entomology "Notes of the Season" June 1908, pp. 190-191.

considerable degree in some fields. The majority of the diseased plants, however, were damaged but little by either insect, and many of them not at all, so far as I could determine. Corn, clover, alfalfa, strawberries and many weeds suffered in precisely the same way, as inferred from their external symptoms, and no insects whatever could be found upon them. I decided the trouble was probably wholly physiological in character, and was in all likelihood caused by the cold, wet spring. Parasites overtook the lice in most localities before they became excessively plentiful."

Prof. Selby in reviewing plant diseases in his report for 1907 says:⁵

"Oats showed a frightful collapse by leaf-blight when the season turned brighter; it seems to have been due to the sudden stress of the change (of weather), possibly aided at times by lice or aphides."

The same disease was evidently quite prevalent in Ontario in 1907. Prof. J. Dearness writing through the *Farmer's Advocate*⁴ in answer to subscribers to that paper, after reviewing Dr. Peck's reports for New York, 1889-90, writes:

"I have examined the specimens of oats received from you, and labelled, respectively, from a correspondent in the county of Oxford; Mr. Twedle, county of Wentworth; Mr. Brodie, Middlesex; and from several other farms in the county of Middlesex.

The disease on all the specimens has similar characteristics. It appears as a blighting of the outer end of the leaf (but not usually of every leaf of the plant) and spreads along the veins towards the stem. As the tissues die, the color changes to a yellowish or reddish brown. I find no mark in root, joint, stem or leaf of the invariable presence of any insect. If the affection were due solely to adverse conditions of soil or weather, all the leaves, as well as the other parts of the plant, might be expected to be similarly discolored."

"His description (referring to Peck's N. Y. State reports) of the affected oat fields agrees exactly with those of your correspondents. The fungus he most strongly suspected at first is present on most of the leaves received here. If it is not the cause, but only a concomitant of the disease, then I should say that we have here either a destructive bacterium to be put in the class with the bacterium of pear blight, or a case of the reduction of the vitality of the oats, by some climatic cause, to such an extent as to permit the invasion of the fungi observed. The problem is an interesting and important one. It may already have been attacked and settled so far as the bacteriologist is concerned. If so, I have not heard the result."

Writing later he says:

"Since reporting to you on the specimens of blighted oat-leaves I have had the opportunity of visiting a number of fields. It may be said of all these that, in general, the stems, youngest leaves and panicles are not attacked by the blight.

In all the grass plants the regions of most vigorous growth are at the joints or just above them, while tissues at the leaf-tips, particularly of the older leaves, have the least vigor. The disease was limited to the latter regions of the oat plant.

I am of the opinion that the blight made no progress after a favorable condition of the weather set in, and that the changes in the color of the leaves and the invasion by fungi occurred and continued in areas of the leaves where the protoplasm had already lost its usefulness to the plant."

⁵Ohio Agricultural Report, 1907, p. 891.

⁴Farmer's Advocate, London, Ont., Vol. XLII, No. 775, Aug. 1, 1907.

The disease was noted in Canada in 1907 as follows:¹⁵

"**Blighting of Oats:** In addition to the above there was a rather wide-spread physiological blight reported during the summer. The trouble was mostly in oat fields and specimens showed the upper parts of the plants as yellowing and dying. Investigation failed to disclose any causative fungi present. The trouble was very probably due to unfavorable weather conditions, the root system having been impaired by a continued cold spell following an earlier warm season, the plants were unable to get proper nourishment and water supply from the ground."

What appears to have been an outbreak of a somewhat similar disease, though apparently not identical, has been described by G. P. Clinton¹⁰ as follows:

"This trouble was first seen at Portland, the second week in June. During June and July it was noticed in almost all the oat fields examined, and so much have considerably reduced the yield. The leaves, especially the lower, became a sickly yellow, and many finally died prematurely. In some respects this trouble resembled the bacterial disease that occasionally occurs in the early summer in the oat fields of the West; but the leaves lacked the water-soaked appearance of that disease, and on examination failed to show any bacteria present. The trouble apparently resulted from unfavorable weather conditions, possibly aggravated by some root disease, though the few examinations made of the roots failed to show any suspicious fungus at work there. June and July had many heavy rain storms suddenly followed by bright hot days, and these sudden changes, as in other cases already mentioned, probably caused the injury. The same trouble was seen to a less degree on a number of other grasses, both wild and cultivated."

EXTRACTS FROM LETTERS—1907.

The large number of inquiries to Farm Journals and letters to the Experiment Station from farmers characterize the disease and emphasize its severity. The following extracts are typical:

"Fayetteville, Brown County, Ohio, 6-9-'07

Dear Sir:

There is something the matter with the oat crop here this season of which you can see by sample No. 2 sent you in this mail.

It looks very much as though some fields are gone entirely now. My oats were the earliest sown in this immediate vicinity and were the last to be attacked by this trouble, that is, a part of the field is turning red very rapidly. There are many of the green bug (aphis) in my field and I was wondering if they are the cause of all this. I am sending blades, both top and bottom and in all stages of color from beginning to end. What is wrong?

BERNARD QUINN."

"Ashtabula, Ashtabula County, Ohio, 6-14-'07.

Dear Sir:

I have been looking over my oats this afternoon and find they are looking much better. Enclosed please find sample of oats.

In travelling around this part of the country, I find the most of the oats are damaged similar to mine. The damage is all on the high ground.

C. J. METCALF."

¹⁵Report of the Ontario Agricultural College and Experimental Farm, Dept. of Botany, p. 49, 1907.

¹⁰Connecticut Agricultural Experiment Station Report 1906, Part V, pp. 316-17.

"Camden, Preble County, Ohio, 6-27-'07.

Dear Sirs:

I am sending under separate cover specimens of oats which I wish you would kindly examine. The oats in this entire country are affected with some disease which causes the leaves to turn brown beginning at the tips. Would you please let me know the nature of the trouble and what we may expect of this land if it is sowed in wheat the coming fall?

D. W. McQUEEN,"

"LeRoy, Medina County, Ohio, 7-8-'07.

Dear Sir:

Will you please tell us the cause of the universal turning red and dying of the leaves on the oats, and what the probable result is going to be?

H. J. FREEMAN."

"Fredericktown, Ohio, 7-3-'07.

Gentlemen:

The oats through this county (Knox) is turning a reddish color of the blades, and seems to be dying.

I examined the roots and could distinguish nothing on the roots that I thought was an insect, excepting on one root.

C. F. BRADDOCK."

EXTRACTS FROM LETTERS 1908-9.

"Ansonia, Darke County, Ohio, 3-7-'09

Dear Sir:

I would like for you to send me a receipt for a dip to dip oats; when my oats get about six inches high it commences to get rusty, and don't grow thrifty, and when it heads it only about half fills the oats. It is all affected the same in this country.

F. J. FOLKERTH."

"Ansonia, Ohio, 3-23-'09.

Dear Sir:

What is it that is in the oats; is it a smut or does it come from the cold weather? The fields of oats get red as fire, that is, the blades. Is there anything that I could do for it?

R. D. FIELDS."

"Wainwright, Tuscarawas County, Ohio, 3-8-'09.

Dear Sir:

My oats are badly infested and yielded poorly the last two years.

GEO. SCHMITZ."

"Camden, Preble County, Ohio, 2-28-'09.

Dear Sir:

Would you kindly inform us as to the advisability of spraying or rather treating seed oats for blade blight?

We were badly infected with this two years since in Preble county.

DR. D. W. McQUEEN."

"Ashland, Ashland County, Ohio, 3-4-'09.

Dear Sir.

Kindly send me formula for treating rust in oats.

PALMER & DONLEY."

"Leipsic, Putnam County, Ohio, 12-28-'08.

Dear Sir:

We had exactly the same disease on our 1908 crop as we did on our 1907 crop, and I am thoroughly convinced if we had not ideal weather for oats crop, we would not have gotten scarcely anything.

I have given the subject very close attention for the last two years and I am thoroughly convinced that it is some disease on the oats and not climatic or weather conditions.

G. O. CRUIKSHANK."

"Fostoria, Seneca County, Ohio, 2-1-'09.

Dear Sir:

Will you please give me directions for treating seed oats that are affected with rust or what ever it is that has caused the oats to turn red before heading out? Oats in this vicinity have not yielded more than half a crop in the last two years, owing, as most farmers believe, to this trouble, although the last season was an exceptionally good one.

J. L. CRUIKSHANK."

"Shelby, Richland County, Ohio, 12-28-'08.

Dear Sir:

Will you please send me instructions how to treat oats for sowing to prevent blight?

R. C. WINBIGLER."

"Polk, Ashland County, Ohio, 1-11-'09.

Dear Sir:

Can the Station give me any information in regard to the condition of the oat crop of last year, which may be beneficial this year?

W. M. FELGER."

The following quotations, taken from the correspondence of Prof. A. D. Selby, Botanist and J. M. Van Hook, Assistant Botanist, in answer to queries in 1907, show many observations which throw much light on the oat blight disease.

"Wooster, Ohio, 6-18-'07.

Mr. C. J. Metcalf,
Ashtabula, Ohio.

Dear Sir:

This form of oat blighting has been quite common at the Station this year, especially on certain varieties, but is largely disappearing with better weather. It does not seem to be due to either insect or fungus, but to conditions surrounding the plant.

J. M. VAN HOOK."

"Wooster, Ohio, 6-28-'07.

Daniel C. Mayne,
Miamisburg, Montgomery County, O.

Dear Sir:

We have the same trouble with oats on the Station farm and have received specimens from many parts of the state. We believe this due to weather and resulting soil conditions more than anything else. There is more of it than I have ever seen before and many varieties on the plots here will be badly damaged even if it lets up at once. With the advent of continued warmer weather, I look for the trouble to diminish, though it made the disease worse at first. However, the green bug or louse, is appearing in numbers in many places and may do much damage unless we have clear warm weather.

J. M. VAN HOOK."

“Wooster, Ohio, 6-29-'07.

Mr. E. W. Falcott,
Kent, Portage County, O.

Dear Sir:

Your oat trouble is a general complaint this year. There were traces of it last year, but nothing like the present. On our variety plots it is very severe. Some varieties are worse than others and worse on high ground, as you say is true in your case. The yellowing of leaves up to this time, at least, seems largely due to bad weather, dark and cold. Increased by the sudden hot weather of the last two weeks.

J. M. VAN HOOK.”

“Wooster, Ohio, 6-29-'07.

Mr. R. S. Shanks,
Ada, Hardin County, O.

Dear Sir:

This seems to be due not to any parasite but to bad conditions of weather. Evidently it has been aggravated very much by the recent change to hot, sunshiny weather, though such a change will doubtless be for the best as soon as the plants become adjusted to these conditions. In many cases the crop is considerably damaged already.

The green bug or plant louse is appearing and is damaging oats quite a good deal, but here on the Station farm parasites are developing rapidly and killing these bugs. Bright weather will do much to stop bug injury.

J. M. VAN HOOK.”

“Wooster, Ohio, 7-2-'07.

Mr. W. M. Cook,
Canton, Stark County, O.

Dear Sir:

Your oats are attacked by aphides (lice) upon the leaves which puncture them and then these leaves subsequently turn red.

A. D. SELBY.”

“Wooster, Ohio, 7-8-'07.

Mr. H. W. White,
Shiloh, Richland County, O.

Dear Sir:

At the beginning of the oat trouble there was a very great abundance of so called green bugs or aphides and the surface of the leaves appeared to have numerous punctures from them. Later with the finer weather the parasites killed off a large number of the lice, but there are still an abundance of leaves to break down, which in part lacks explanation. Latterly, however, the new leaves formed are all right and the shortage in the crop from the attack will probably not be excessive.

A. D. SELBY.”

“Wooster, Ohio, 7-12-'07.

F. S. Aten,
Nevada, Wyandot County, O.

My Dear Sir:

This leaf blight has been under study here for some time. I first observed it about three weeks ago and associated with it then were very large numbers of plant lice (greenbugs). When the fine weather came on the para-

sites killed off the plant lice and since then the leaves have kept dying in most localities without our being able to explain just why this kept up. Possibly the lice attacks had something to do in the beginning, and the turning to hot weather some more. We do not expect an ordinary oat crop and especially with the later sorts. Early sorts ought to make 3-4 of a crop here but the later sorts little more than 1-2 crop, I fear.

A. D. SELBY."

"Wooster, O., 7-22, 1907.

Mr. F. P. Stump,
Convoy, Van Wert Co., Ohio.

My dear Mr. Stump:

You have doubtless seen the press bulletin issued by the Station with respect to this leaf blight of oats. In the beginning some four weeks ago the crop of aphides (green bugs) was so great as to be held responsible. Later on the leaves continued to blight even after the parasites had killed off the plant lice. Possibly for physiological reasons, the leaves continued to break down.

A. D. SELBY."

"Wooster, O., 7-22, 1907.

Mr. C. P. Oferholtzer,
Hoytsville, Wood Co., Ohio.

Dear Sir:

The head of oats which you send shows what we call "blast" and this serious blast is no doubt due in part to the leaf blight that has been prevailing.

A. D. SELBY."

The severity and nature of the disease is quite readily understood from the above quotations. Though worded differently and emphasized from different standpoints, yet it is quite conclusive that the same general type of trouble was evident in all cases, except possibly the one reported from Connecticut in 1906. The writer finds that the disease differs greatly in its field aspects. Only under the most favorable weather for the spread and development of the disease, does the trouble assume such pronounced and severe characteristics as were manifested through the central and eastern states in the season of 1907. Under weather conditions more conducive to the growth of oats, and less suitable for the aggressive action of the parasites, the appearance of the trouble becomes entirely changed; leaves which were but partially infected and which under trying conditions would have turned brown in less than a week, under favorable conditions take on a light, yellowish color and may even assume later a natural green. Extensive observations were made upon the disease in the field and under control conditions in the greenhouse, and it is evident that the disease manifests its presence by changes in color varying from a light yellowing, which apparently checks but little the growth of the oats, to a pronounced reddening, which in severe cases kills the blades, leaving only the younger leaves and the central axis alive.

COMMENTS UPON THE ABOVE EXTRACTS.

In a review of previous literature upon this oat blight it is apparent that in only one instance has definite infection work been carried on to determine the cause of the disease, in which case Galloway and Southworth find two bacteria; one of which, they report, produces the blight when inoculated into the oats. This work as reported in the above citation covered but one phase in the study of the disease, and apparently required verification before it could be accepted. A fuller and more extensive report is desired from these workers, covering the several phases of this disease, in order that the organisms may be limited and the nature of the disease more fully understood.

G. P. Clinton, in the 1906 Report of the Connecticut Station, stated that he found no bacteria associated with the yellowing of oats as prevalent that season. From his report it would appear that probably only microscopic examination was made. If such was the case and no cultures were run, it could yet have been a bacterial disease, and the organisms easily missed. On the other hand, cultures would quickly show whether bacteria were present or not. He doubts whether the disease is identical with the bacterial disease noted in the western oat districts.

From a careful study of Pettit's work and notes in Michigan in 1907, (Bul. 251, Mich., March, 1908) it appears rather clear to the writer that the oats in that state were subject that season to both the thrips injury and the bacterial blight. His careful description of the field manifestations, and his illustration, Fig. 3, p. 114, are very typical of the bacterial blight. His illustrations, Figs. 4 and 5, on the other hand are very typical of insect work. It is possible that the thrips were a means in the distribution of the bacterial blight.

In reviewing the literature on the 1890 outbreak of oat blight, we find Galloway and Southworth note: "The disease (ascribed to bacteria) extends from New England to Georgia, and from the Atlantic Coast as far west as Indiana and Illinois. It is not present in Michigan." In notes upon the same year (1890), F. L. Washburn, writing in Bul. 108, p. 264, Minn. Experiment Station April, 1908, on the work of *Toxoptera graminum* says: "In 1890 it was found in injurious numbers on wheat in Indiana and in certain sections of that state the oat crop was a failure through its ravages." It is even possible that the diseased condition of oats in Indiana as noted by the two different writers above for 1890, was due to the same causes, and resulted from the combined work of aphides and bacteria.

The description of the field conditions, given by the others quoted, are all apparently very similar to those given by Galloway and Southworth; and although the causes assigned are, in general, entirely at variance, the writer believes the disease in each instance is the same, and due to bacteria as isolated by the authors noted above; however, instead of assigning the cause to *one* of the organisms, the writer finds the disease to result from a mutual relationship of the two organisms. That this conclusion is correct appears evident from experiments carried on the past two seasons, (see p. 107 and following).

THE BLIGHT DISEASE NOT RESTRICTED TO OATS.

Among the observations made by others in the past upon the blight disease, there are several in which are noted somewhat similar troubles upon wheat³, grasses¹⁰, alfalfa³ and other crops^{2 3 10}. The writer has carried out much preliminary culture work on the several different kinds of plants which have shown yellowing or blight symptoms, and although this work has not been supported by extensive inoculations as with the oats, the evidence is sufficient to show that the disease may and does affect some of the more susceptible varieties of other plants.

During March, April and May of 1909 inoculations were made in the pathologium on wheat (Gypsy and Poole) and corn, on three different occasions, covering periods of different atmospheric conditions. In no instance did either of these varieties of wheat show signs of infection; however, with the corn, during a cloudy, moist period, several of the lesions spread quite rapidly, from which at a distance of twelve inches from the point of inoculation, by means of plate cultures, the organisms of the disease were separated.

During the present growing season (1909) careful observations have been made on all the varieties of wheat, oats, barley and other crops grown at the Station, for the appearance of this disease. On one variety of wheat, known as Extra Square Head, recently brought here for trial, the blight at a period favorable for its development showed quite extensively. Cultures readily showed the specific organisms to be present. Among the other wheat varieties not a trace of the disease could be found.

There are on wheat and other plants several different fungi, which in their preliminary attack bring about a yellowing that could, off hand, easily be classed with the bacterial blight of oats. Mildew and rust on both wheat and oats may cause yellowing in moist, cloudy weather, which when followed by hot, clear, droughty weather, will cause the blades to turn quite red.

The leaf-spot of alfalfa when severe may cause yellowing. The same is true in leaves of other plants affected with fungous troubles.

As is noted elsewhere, among the oat varieties considerable difference is seen in resistance to this disease.

Among the barleys grown at the Station, one variety, known as Primus, showed a susceptibility to the disease even more marked than did the Wideawake variety among the oats. The Oderbrucker variety of barley also showed an occasional blade infected. These observations were verified by cultures.

What appears to be the same disease has been observed on the blue grasses and timothy; in these cases, however, instead of the blades yellowing, the disease appears restricted to the culm, at heading time, causing, just above the upper joint, a limited lesion which kills the upper part of the stem and causes the head to dry up or blight. This type of injury, off hand, appears similar to insect work, but examination by stripping down the sheath, fails to show that insects are present, or signs of boring; cultures and micro-examinations reveal blight bacteria as the cause. These observations have not been followed up by inoculation work. Infection just above the upper joint would appear to be a matter of spattering by rain above the sheath, and running down between the sheath and stem rather than infection from below, passing upward through the vascular system.

During the growing seasons of 1908 and 1909 considerable culture work was done upon yellowing alfalfa, especially upon those plants showing much yellowing and little leaf-spot (*Pseudopeziza medicaginis*). In many instances the presence of bacteria, in the stem and upper leaves, sometimes in large numbers, showed conditions entirely abnormal. The significance of these conditions requires much further investigation. The writer is of the opinion, that alfalfa, on many of our soils, has to contend with certain bacteria which are somewhat specific in their attack upon the plant. Whether these bacteria are the same as those which cause oat blight or not, has not been worked out; however, upon preliminary plating they are very similar.

As noted elsewhere (p. 122) it is probable that the bacterial flora has much to do with the health and growth of certain crops. In this respect alfalfa may be much more exacting than many of our other crops. Experiments carried out in the pathological garden in 1908 and 1909, in soil above the average in fertility, on which were planted red clover, alsike and alfalfa, showed that the red and alsike clovers produced an excellent growth, while the alfalfa was very weak and yellow. Leaf-spot was present on the alfalfa, but not to such an

extent as to account for the weak, yellow growth. An examination of the root systems showed the red clover and alsike to be abundantly supplied with nodules, while the alfalfa had none on many plants and very few on any. Plate cultures made from leaves and stems of the alfalfa showed many internal bacteria, while the red and alsike clovers showed no such abnormal condition. From such evidence it seems probable that either certain specific organisms, or the bacterial flora and its by-products, were not favorable to alfalfa.

DISTRIBUTION OF THE BACTERIAL BLIGHT OF OATS.

From the literature quoted it is very apparent that the disease is of wide distribution. Depending on seasonal conditions the disease manifests itself from the Canadian lake provinces on the north, to the gulf states on the south, and from the New England and middle Atlantic states on the east, to Illinois and states south thereof, on the west. The writer is of the opinion that not a season passes but the disease shows itself in at least a limited way in some locality of the area included above. It requires but ten days to two weeks of favorable weather to bring about preliminary infection. The amount of this infection apparently depends upon the height of oats, the amount of spattering, association of insects, and the continuance of cloudy, humid weather.

AMOUNT OF LOSSES OCCASIONED BY THE BACTERIAL BLIGHT OF OATS.

It is very difficult to estimate the exact amount of loss occasioned by an outbreak of fungous or insect trouble, owing to the fact that several factors are always at work. The plant pathologist is inclined to emphasize the destructive work of fungous and bacterial diseases, while on the other hand the entomologist chiefly sees the work of the insect. If we are to draw our conclusions from a general summary of previous literature on oat blight we can readily see that the losses have been very large at times. The seasons of 1890 and 1907 as well as 1908, were the ones in which the oat blight was by far the most general and destructive. A comparison of the yields in Ohio for these seasons, with the average yield for the past 18 years, shows a shortage respectively of 36.7, 24.3 and 14.4 percent, or stated in bushels per acre, for the above three seasons the yield was respectively 19.8, 23.7 and 26.8 bushels as compared with an average of 31.3 bushels per acre for the past 18 years. (See Table II, showing acreage, yield, etc., from 1890 to 1908 inclusive).

The literature quoted clearly points out the losses as indicated by field conditions. That these losses in some localities have been very much in excess of those in others is evident from the observations noted in the correspondence (See letters, pp. 97 to 101).

Several of the writers indicated the prevalence of the disease with much loss for three seasons consecutively. Such prevalence of the disease means that these certain localities have been subject to an excess of rainfall, cloudiness, etc., furthered by the soil becoming filled with the organisms responsible for the disease.

TABLE I: Showing oat acreage, yield and seasonal conditions
in Ohio from 1890 to 1908 inclusive.

Year	Acreage	Bushels produced	Yield per acre	General condition of growing season
*1890	959,012	19,049,033	19.8	Season very late, seeding much delayed through excess rains, oats late, badly blighted.
1891	879,463	26,515,935	30.1	(Failed to obtain data.)
1892	827,823	22,541,473	27.2	Very wet and unfavorable for seeding. July very droughty.
1893	856,235	24,537,989	28.6	April and May very wet; June and July droughty, oats short.
1894	1,051,773	31,991,896	30.4	Season as a whole very favorable, with good promise.
1895	1,095,142	34,013,739	31.06	May favorable for acreage. June and July condition generally low.
1896	1,262,805	36,027,464	28.5	Very favorable season for large acreage. Growing season good. Large oat crop is the prospect.
1897	1,052,605	30,563,033	29.	May very wet, oat seeding generally delayed. Acreage small. June and July conditions fair.
1898	976,902	30,694,432	31.4	May not favorable for large acreage. Much injury in June on low grounds from heavy rains.
1899	969,565	33,296,912	34.3	Oat seeding rather late. Drought through June and July, plants short, but filling well.
1900	1,251,248	43,193,577	34.5	May favorable for large acreage, but rather dry for good growth. July very favorable.
1901	1,053,876	33,936,143	32.1	Seeding late, but June quite favorable, though heavy rains. July favorable.
1902	1,188,947	46,789,843	39.3	May favorable for acreage and growth; June conditions fair; July fair except on low ground, injury from rains.
1903	1,213,228	37,305,993	30.7	May favorable for large acreage, but quite dry. June conditions good. July conditions good. Some red rust.
1904	1,467,052	58,312,740	39.7	May very favorable for seeding. June favorable. July favorable.
1905	1,419,112	49,731,954	34.3	May very wet; June conditions fair. July oats doing nicely.
1906	1,343,247	44,179,782	32.9	May, heavy rains, seeding retarded. June, dry and not favorable for growth. July, oats doing poorly, though slightly better than June.
19 7	1,429,792	33,906,233	23.7	Spring very wet, season late, cold, cloudy, oats generally blighted.
1908	1,281,805	34,363,980	26.8	May unfavorable for seeding. June conditions favorable. July droughty, condition not good.

Average yield of oats for eighteen years, (1890 to 1907) 31.3 bushels per acre.

* From the Ohio Statistics, Report of the Secretaries of Agriculture.

NOTE: The bad blight years for oats, viz., 1890 and 1907 show respectively a reduction in yield of 36.7 percent and 24.3 percent from the average for the past 18 years.

THE OAT BLIGHT CAUSED BY TWO SPECIES OF
BACTERIA IN SYMBIOTIC RELATION.

At the present day it is well known that relationships among organisms greatly retard or increase their virulence, and also the possibility of disease production. Dr. W. E. Musgrave¹⁴ emphasizes the importance of symbiosis existing among organisms pathogenic to animals. In reviewing this work¹⁵ W. A. Hooker, in the Experiment Station Record, writes as follows:

"The influence of symbiosis upon the pathogenicity of micro-organisms: Bacterial and animal symbiosis are discussed at length by the author. Many of the phenomena not now understood in the etiology and pathology of disease are said to be due to symbiotic combinations between the micro-organisms. Variability in the virulence of bacteria is one of the most marked features and the reason for this variability is but partially understood. The author concluded that, 'the most promising field for laboratory research in the future will be the study of cause and effect, in the complex relation and interaction of micro-organisms with each other and in their environment of complex symbiosis and the ever changing and multiple conditions found in hosts.'"

The experiments carried out with the oat blight organisms clearly substantiate the statements made by Dr. Musgrave. Not alone is the production of disease apparently very dependent upon the symbiosis of these two organisms, but it is found also that the virulence and viability of the white organism (*Psuedomonas avenae* n. sp.) upon artificial culture media, depend greatly upon the association with the yellow organism (*Bacillus avenae* n. sp.) in mixture. The extent of this interrelation as exhibited in disease production is clearly shown in the illustration, Plate I, in which the two rows at the right were infected with a mixture of the two organisms, while the fourth and fifth rows from the right were infected respectively with the yellow and the white organism separately. Where the mixture was applied the blight resulted in twelve days, but where the organisms were infected separately no typical blight resulted. The yellow organism produced no lesions at all and the white organism produced but limited and non-typical lesions. In carrying cultures through the winter the writer had several series of cultures from different sources in which in some instances the organisms were carried through separately, while in other instances the organisms were carried over as mixtures. In renewing these cultures, at the end of a period of nearly nine months, it was found that the white organism, where carried over in pure culture, in several cases failed to grow, but in every instance where it was carried over in mixture with the yellow organism the viability and virulence of the former organism were more marked than when carried over separately.

¹⁴ Philippine Jour. of Sci., B., Med. Sci. 3 (1908), No. 2, pp. 77-88.

¹⁵ Experiment Station Record, Vol. XX, No. 8, p. 758 1909

DESCRIPTION OF PLATE I.

Showing, in the two rows at the right, results of the infection with a mixture of artificial cultures of the yellow and white bacteria (*Pseudomonas avenae* n. sp. and *Bacillus avenae* n. sp.) of the brown blight of oats, inoculated by means of a hypodermic needle, twelve days prior to the time of photographing. The blades in the infected row at the right were inoculated in the leaves about one inch from the tips. In the infected row, second from the right, the plants were inoculated near the base of the leaves and also through the stems; the infection in this row greatly retarded the growth of the plants and several even succumbed to the disease. (See Plate II showing the condition of this row as compared with the check, photographed two weeks later). The row at the left of the infected (three rows from the right) is a check row in which the leaves were pricked with control punctures from which no injury or blight lesion resulted. The fourth row from the right was inoculated with the yellow organism, (*Bacillus avenae* n. sp.) from which no lesions resulted; the fifth row from the right was inoculated with the white organism (*Pseudomonas avenae* n. sp.) and the results were, lesions formed slowly, extending about one-half to one inch from the point of infection, then remained checked. The evidence of the symbiotic relationship existing between the organisms which produce the blade blight of oats is clearly brought out in this experiment. By one eighth.

3-11-09. Original.

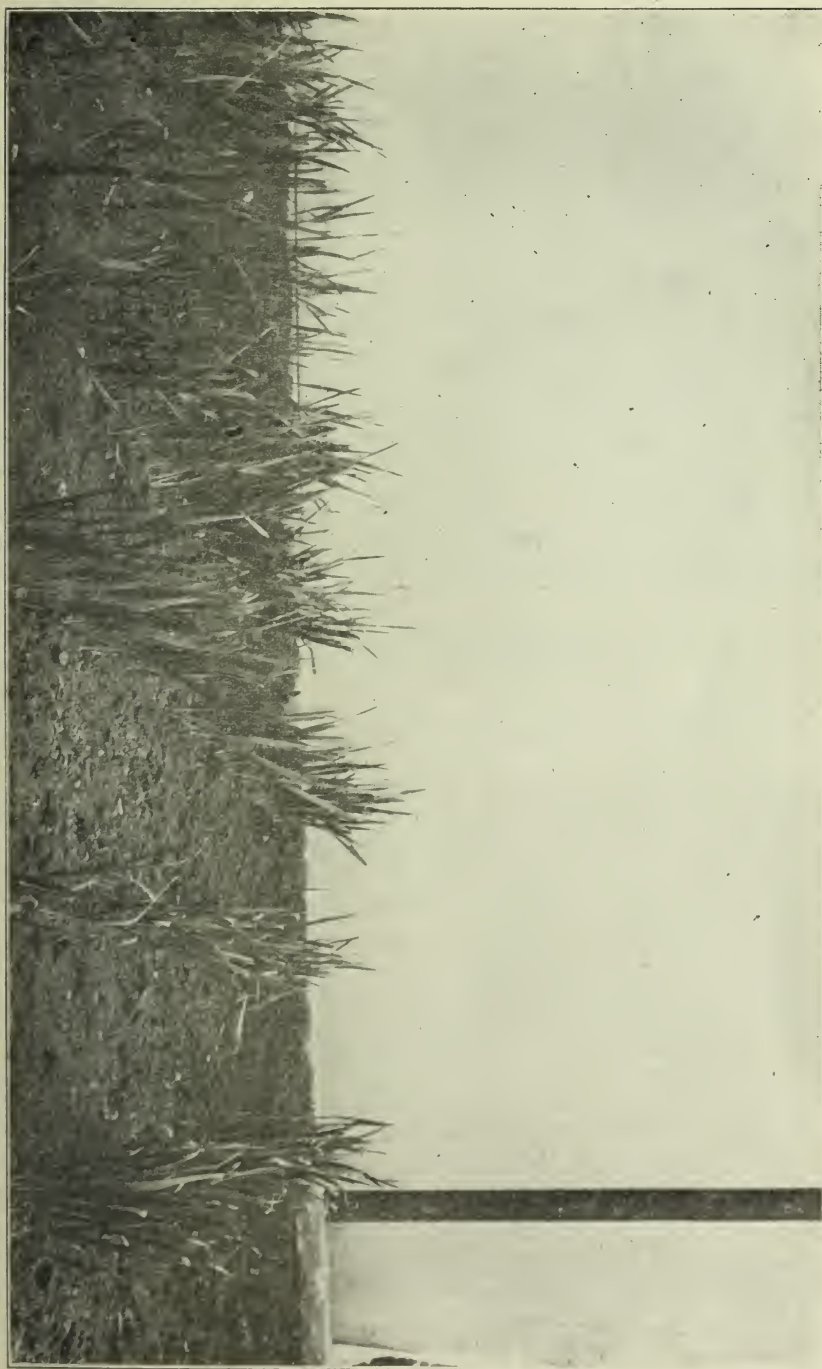


PLATE I.

The influence of mutualism upon the virulence and activity in disease production became much more noticeable when cultures of the white and yellow organisms, which had been carried over separately in pure cultures, were mixed and attempts were made to infect the oat plants, in which case the infection was very slow and required more than a week's difference in time before the lesions became active and typical, as compared with those inoculations from cultures carried over as mixtures. In the latter case the infection was noticeably active from the time of inoculation, clearly showing that the relationship of the yellow organism with the white assisted in some way in keeping up the virulence of the latter. As stated above, the white organism (*Pseudomonas avenae* n. sp.) when inoculated alone into the oat plant produced limited lesions, which were much lighter in color than those produced when a mixture of the organisms was used. In practically all cases of separation of organisms from diseased oats these two bacteria were found more or less abundant, thus again tending to show that the disease is a result of a symbiotic relation between these organisms.

OTHER OBSERVATIONS WHICH POINT TO BACTERIA AS THE CAUSE.

The outbreak of the blight on the Ohio Experiment Station grounds at Wooster, in 1908, caused very little loss, though at one time it was quite threatening. During that season the aphides were more or less associated in the spreading of the infection. One incident pointed very clearly to the probability of the trouble being bacterial. The Agronomy Department carried out a clipping experiment on oats to learn if stand and yield could be bettered. At the time of this clipping the blight was quite conspicuous. The work of the sickle in cutting through the infected leaves was a means of generally spreading the blight throughout the plots. In less than two weeks each of the clipped plots showed a very marked contrast in the amount of disease as compared with the plots which had not been clipped.

Further evidence was gathered the present season (1909) when the blight made its appearance with no insect complications. The disease in the majority of infected leaves began as small yellow spots on different parts of the blades. When these points of infection were numerous the infected areas quickly became confluent, and the collapsed leaf showed a brownish, mottled appearance. Occasionally infection was observed which began on the sheath near the midrib, resulting in a light, yellow streak extending clear to the end of the blade. This streak later turned brown (see Plate XIII).

THE POSSIBILITY OF OAT BLIGHT FROM OTHER CAUSES.

Insect relations: In a review of literature bearing upon the oat blight suggestions are found, that point to other factors that may be important in causing blight diseases of oats. Prominent among these causes are mentioned insects, for examples, such as *Macrosiphum granaria*, *Syphocoryne avenae*, *Toxoptera graminum*, *Anaphothrips striatus*, *Coleothrips tri-fasciata* (*Thrips trifasciata*) and others. The writer would find it somewhat out of his line to experiment with each of these organisms as to the type of injury they would produce on oats. However, in order to obtain data on the relationship of the grain aphides found prevalent upon oats in this vicinity during the seasons of 1907, 1908 and 1909, the writer carried out a number of experiments, all of which show that these grain lice are not the primary cause of the blade blight of oats. Further, that the type of injury produced by them is very characteristic and easily recognized from the bacterial blight. While the blight disease was prevalent in 1908 (June) the writer gathered a number of oat aphides feeding on blight infected plants. These insects were caged with young oats that showed no sign of the blight disease. Ten to twelve days after the caging the blight began to show, while the check outside the cage remained free. It was observed that, on several of the leaves most thickly covered with aphides, no yellowing was apparent. Plate cultures of the yellowing leaves showed the blight bacteria plentiful, while cultures from those blades on which were many insects, but which showed no yellowing, gave, on the contrary, no blight organisms. This pointed to the probability that the aphides were simply means in distributing the disease. Cultures were then made of live aphides to learn whether the bacteria were surviving internally (see lower ill. Plate V). It was evident that the bacteria were present in abundance within the insects and likewise very viable. Inoculations into oats with a mixture of these bacteria, taken from aphides, produced infection resulting in the typical brown blight.

In order to further investigate the relationship of aphides to this bacterial blight, more extensive experiments were planned and carried out during the months from January to June 1909. Oat aphides apparently free, that is, not carrying the bacterial blight, were confined in a cage on oats, from the time when the oats were two weeks old until they were two and one-half months old. The oats at the age of four weeks were literally covered with the aphides of two different species. (See Plates III and IV and their descriptions). The type of injury caused by these insects came on very slowly and differed greatly from the bacterial blight, infections of which were running simultaneously. (compare Plate IV with Plate X).

DESCRIPTION OF PLATE II.

Showing the effects of the blade (bacterial) blight of oats upon plants five weeks old. The row at the right was inoculated when the plants were one week old (only two leaves out) through the sheath and leaves by means of a hypodermic needle with a mixture of artificial cultures of the yellow and white bacteria (*Pseudomonas avenae* n. sp. and *Bacillus avenae* n. sp.) of oat blight. Ten days after the inoculations the leaves showed the typical preliminary yellowing of the brown blight. Check punctures were made in the control row at the left with no resulting lesions. Twelve days after the row was inoculated, both rows were caged in and grain aphides, two species which were free from, that is, not carrying the bacterial disease, were placed on the sick row to learn in what time the blight would be transferred by these insects to the control row; in two weeks the infections were quite general, being carried by the aphides from the sick row to the check row. This experiment clearly shows the relationship of grain lice to the bacterial blight of oats. By one-sixth.

3-26-09. Original.

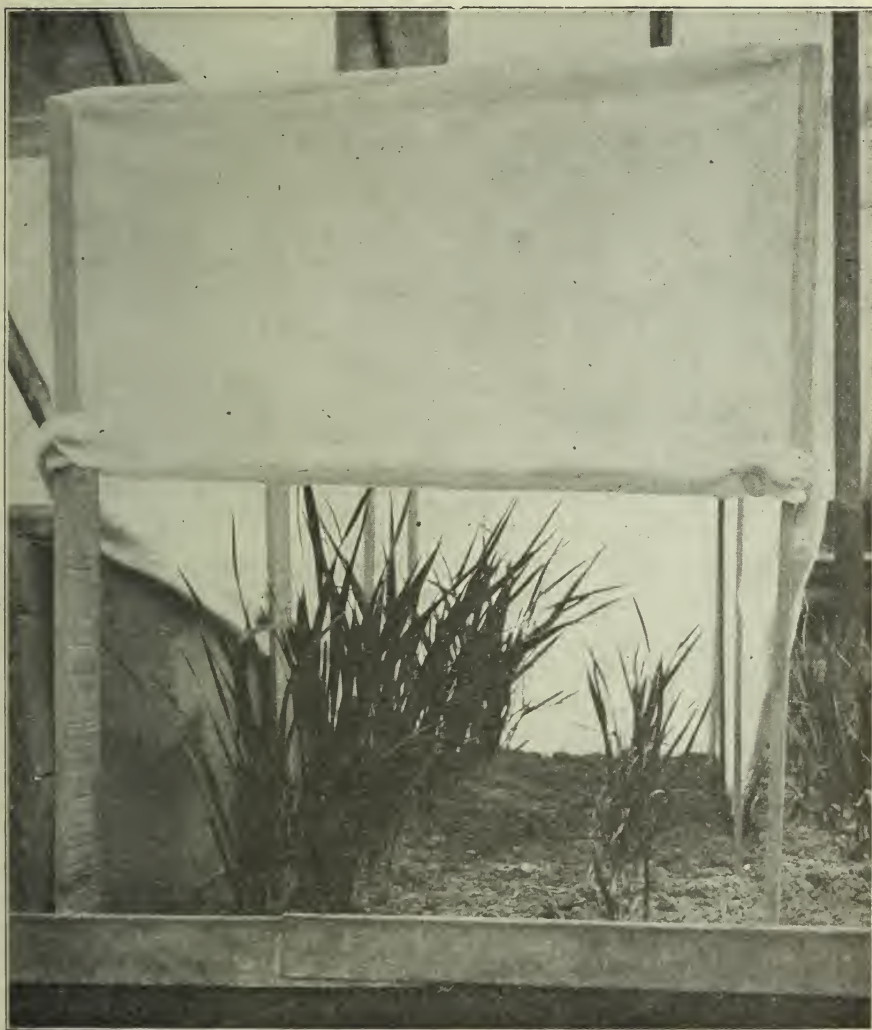


PLATE II.

DESCRIPTION OF PLATE III.

Showing cage containing oats on which two species of grain aphides worked for 2 1-2 months until the oats were literally covered, without producing the blade blight. (See illustrations in Plate IV.) The insects were apparently free from the bacteria which cause the blade blight of oats. The result of the work of aphides on oats differs entirely from the bacterial blight (compare Plate IV, Fig. 3, showing aphid work, with Plate X showing bacterial blight). At the time the above photograph was taken the aphides had been at work seven weeks and literally covered the oats. This experiment clearly shows that grain lice are not the primary cause of the oat blight. By one-sixth.

3-26-09. Original.

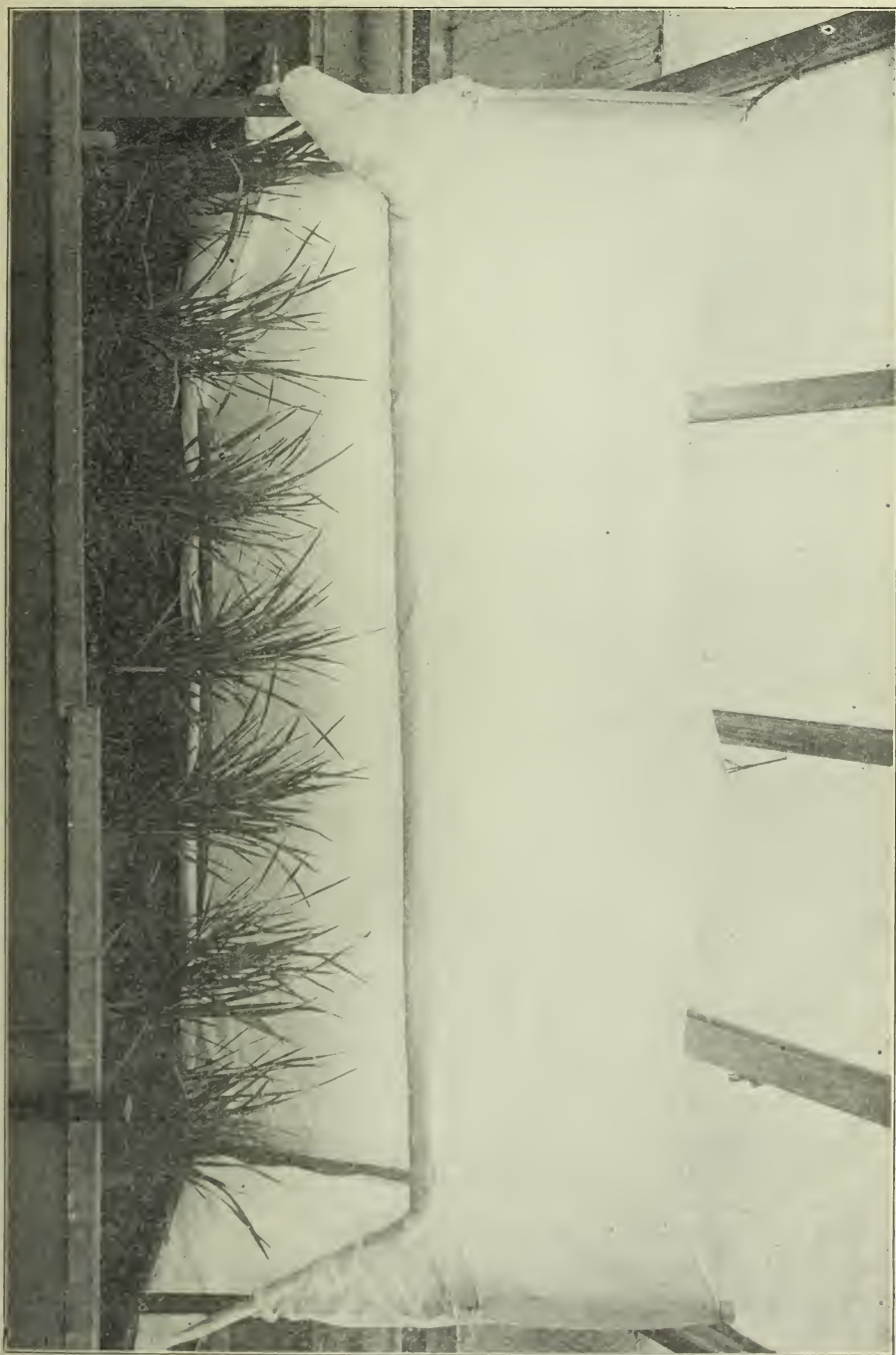


PLATE III

Further, to demonstrate the relation aphides bear to the spread of the disease, an experiment was carried out as follows: Oats well along with the bacterial infection were covered with aphides and caged in, along with a check (healthy) or non-inoculated row, to learn whether it were possible for the insects to carry the disease from the sick plants to the healthy plants, and if so, in what time. This experiment demonstrated that aphides were carriers of the disease, and the time required for visible infection was practically the same as from inoculation by hand, viz., seven to fourteen days; (see Plate II and description). This again verified the conclusions reached in 1908, and showed that aphides are only a secondary factor in the spread of the blade blight.

The direct result of aphid-sucking on oats may be called a blight, but of a nature entirely different from the bacterial blight.

EXPERIMENTS TO DETERMINE THE NATURAL MEANS OF INFECTION.

The general prevalence of the disease would suggest the probability of a trouble surviving in the soil. If such were the case, one would suspect infection to take place through one of two methods, viz., by penetration of the roots, followed by a traversing of the vascular system, finally working its evil effects throughout the leaves, or by rains spattering the disease upon the leaves and the infection taking place through the stomata. Experiments were run to learn whether either of these methods would bring about infection. Following the first method, virulent, artificial cultures of a mixture of both organisms were poured directly upon the root system, the latter being partially uncovered. No infection took place, though the atmospheric conditions maintained were the most favorable. Seed thoroughly soaked in mixed cultures of the organisms previous to planting failed upon growing, to show any blight.

Following the second method the writer took similar cultures and sprayed upon the blades. Infection followed within twelve days, identically of the same type as observed in fields, thus showing that stomatic infection is possible, and probably the chief way; the disease being spattered on by rains. These experiments were carried out in the pathologium in March and April, 1909. In 1908 similar spraying infections were carried out, with this difference, that one series of leaves were slightly bruised previous to spraying. The results were that the leaves previously bruised took the infection much more readily than did the unbruised, though the disease was present on both. This would suggest that heavy, beating rains which cause light bruises on the foliage might be a means of bringing on active infection.

Secondary infection by insects proved a further means in the distribution of the disease, as noted elsewhere. It was thought possible that the disease might be related to the apple blight and that probably aphides were carrying it back and forth, as it has been noted that *Macrosiphum granaria* and *Syphocoryne avenae*¹³ pass part of their existence on the apple. The writer gathered twigs of apple affected with blight and numerous twigs covered with aphid eggs, and bred the insects from the latter in cages containing oats. In two series of experiments along these lines, the insects on hatching failed to transfer themselves to the oats, though several generations were produced on the sprouting apple twigs. These experiments would seem to indicate that the eggs found so prevalent on the apple in 1908-09 were not those of *Macrosiphum granaria* or *Syphocoryne avenae*, but probably *Aphis mali*. (See Figs. 1-2-3, Plate XV). Cultures made of the apple and pear blight organism showed it to be entirely different from the white organism, *Ps. avenae* n. sp., of oat blight.

THE BLIGHT OF OATS IN ITS RELATION TO ATMOSPHERIC CONDITIONS.

The disease in its relation to weather conditions is very similar to that of the late blight of potatoes¹⁸, and the blight of pear and apple. The former is known to be a disease prevalent during those seasons when much rain, cloudiness, and wet, muggy weather prevail. Every plant disease may be said to have its certain favorable meteorological conditions. Whetzel¹⁹, writing on the bacterial canker of apple, states:

"It is well known that the 'blight' in the twigs of pear and apple trees is more active and severe during a continued period of warm, muggy weather. The same is to be said of the cankers on the limbs and bodies of the trees. It was repeatedly noticed during the past season that the active spread of the cankers was coincident with certain periods of rainy weather. The progress of the disease through the bark is always abruptly checked on the appearance of bright, sunny days. The recurrence of favorable weather may often cause a renewal of activity, the canker spreading and increasing its former extent."

From observations of field conditions and control experiments in the pathologium, the writer is convinced that the chief factors in the spread and production of the blight disease of oats are rains, excess of humidity and cloudiness. Excess of these conditions reduces the vitality of the oat plant and leaves it undoubtedly much more susceptible to the disease. Primary infection is chiefly stomatic, resulting from the spattering of the organisms upon the blades by the rain. Following such means of infection it would be

¹⁸ A. D. Selby, Ohio Naturalist, Vol. VII, No. 4, pp. 79-85, 1907.

¹⁹ The Blight Canker of Apple Trees by H. H. Whetzel, February, 1906, Bulletin 236, Cornell University Experiment Station.

logical to expect the most rapid spread of the disease during periods of rainy, cloudy weather. Control experiments, in which the air was kept nearly saturated and plants well watered, readily showed that these were the conditions most favorable for the aggressive growth and spread of the disease. Under such conditions the amount of infection following inoculation was nearly 100 percent. On the other hand, under experiments in which the air was kept dry, the plants sub-watered, and in which the sun was bright, the disease was quickly checked and the plants quite readily outgrew the injury. The percent of infection following inoculation under such conditions was very small.

The writer, in carrying out experiments under Prof. Bolley, of the North Dakota Experiment Station²⁰, in the study of the ascension of sap in tree medication, observed that, on days of much sunshine and little moisture in the atmosphere, the ascension of sap and the capability of the tree to feed were excessive, as compared with those days when the atmosphere was nearly saturated and the sky heavily hung with clouds. In the latter case it was observed that often the tree, instead of being capable of feeding, actually had an outward or back pressure which could be compared to the spring flow of sap during sugar harvest. It is believed by the writer that this stagnation of the sap within plants during moist, cloudy weather offers to certain specific organisms a medium very suitable for their growth, while on the other hand, the plant under such conditions is prohibited from producing protective enzymes which are more or less capable of destroying or preventing the invasion of bacterial parasites. A cold or cool atmosphere, other conditions being practically equal, is more favorable for the spread of the bacterial lesions, than is a warm atmosphere. This was clearly proved by experiments running simultaneously under cool and warm conditions in the pathologium during February and March, 1909. These experiments were duplicated with similar results. In the cool room, which was directly connected with the warm apartment (the temperature in the latter being maintained by artificial heat) the lesions spread with much more rapidity than those in the plants under warm conditions. This would appear to be the prevailing condition in 1907 (see Table II, p. 121).

In the case of the oat blight, should the disease reach the stage in which the leaves are generally yellowed, and following which, the weather suddenly changes from a cloudy, moist condition to that of bright sunshine with quick drying, the extent of the injury becomes greatly aggravated. The majority of infected leaves quickly take on a brown color and entirely collapse.

²⁰ Fourteenth Annual Report of the N. Dak. Agric. Exp't. Sta. for 1903 pp. 55-58.

The data summarized in Table II, pp. 119-121, show the meteorological conditions for the years 1890 to 1909 inclusive. By a glance at this table, the season of 1907 (the year of general oat blight), is to be noted as very abnormal throughout the growing period in April, May, June and July. The temperature for these months ranged respectively 7.2, 6.8, 4.0 and 1.3 degrees below the average normal. The general cloudiness was very excessive. These two factors, together with the prevailing wet spring, were ideal for the activity of the bacterial blight. That low temperature is not the chief factor in blight production is evident when we compare the growing season of 1890 with that of 1907, in which former year the blight was much more severe. The temperature variations in 1890 for the months of April, May, June and July were +1.5, -1.4, +3.8 and -6.2 respectively, from the normal. The month of June, the time when the greatest blight distribution and injury take place, shows a high average temperature.

TABLE II: Showing the variations in mean temperature and rainfall in Ohio for the months of April, May, June and July from 1890 to 1909 inclusive.

Also number of cloudy and partly cloudy and rainy days for the same period.

	1890				1891			
	Temp. variation from normal	Precipitation variation from normal	Cloudy days Total Partial	Rainy days Total + traces	Temp. variation from normal	Precipitation variation from normal	Cloudy days Total Partial	Rainy days Total + traces
April.....	+1.5	+ .68	18.5 8.8	*12+2	+2	-0.57	18 9	*12+3
May.....	-1.4	+1.25	23. 10.9	17+2	-1	-1.84	19 10	11+2
June.....	+3.8	+ .65	18.8 14.2	15	+2	+0.85	17 12	15+1
July.....	-0.2	-1.38	13.2 10.3	7+2	-4	+0.41	15 10	11+1
	1892				1893			
	Temp. variation from normal	Precipitation variation from normal	Cloudy days Total Partial	Rainy days Total + traces	Temp. variation from normal	Precipitation variation from normal	Cloudy days Total Partial	Rainy days Total + traces
April.....	-1	+0.56	22 11	14+3	+0.6	+3.29	25 10	18+3
May.....	-1	+2.09	25 11	17+2	-1.3	+0.37	25 11	12+3
June.....	+3	+1.42	21 13	19+3	+0.7	-0.74	21 15	14+1
July.....	N	+0.37	16 12	10+3	+1.6	-0.88	16 13	9

* Data in these columns taken at Wooster, Wayne County, O. The other data is the average from all other weather stations of the state.

† See bottom, p. 121.

TABLE II: Continued.

	1894				1895			
	Temp. variation from †normal	Precipitation variation from †normal	Cloudy days Total Partial	Rainy days Total + Traces	Temp. variation from †normal	Precipitation variation from †normal	Cloudy days Total Partial	Rainy days Total + Traces
April	+0.6	-0.71	19 8	*12+4	+1.6	-0.85	19 11	*10+1
May	+0.4	-0.55	23 12	18+3	+1.3	-4.34	18 11	8+4
June	+1.2	-1.33	15 12	8+4	+1.7	-1.40	15 10	3
July	+1.3	-1.66	14 12	6+2	-1.2	-1.12	24 14	7+2
	1896				1897			
	Temp. variation from †normal	Precipitation variation from †normal	Cloudy days Total Partial	Rainy days Total + Traces	Temp. variation from †normal	Precipitation variation from †normal	Cloudy days Total Partial	Rainy days Total + Traces
April	+6.3	-0.16	20 10	11+3	-1.2	+0.30	11 10	12+3
May	+7.5	-1.55	19 13	15+3	-3.9	+0.05	20 12	11+2
June	-0.7	+0.87	20 15	17+2	-2.0	-0.97	17 13	7+4
July	+0.3	+4.63	11 12		+2.4	+1.09	19 14	12+3
	1898				1899			
	Temp. variation from †normal	Precipitation variation from †normal	Cloudy days Total Partial	Rainy days Total + Traces	Temp. variation from †normal	Precipitation variation from †normal	Cloudy days Total Partial	Rainy days Total + Traces
April	-3.0	-0.60	18 9	9+4	+2.2	-1.58	21 12	11+5
May	+1.	+0.12	21 11	14+3	+2.4	+0.69	28 17	14+4
June	+1.5	-0.90	13 10	6+4	+1.2	-0.56	12 8	11+6
July	+2.8	+0.40	16 12	9+7	+0.2	+0.22	18 12	13+2
	1900				1901			
	Temp. variation from †normal	Precipitation variation from †normal	Cloudy days Total Partial	Rainy days Total + Traces	Temp. variation from †normal	Precipitation variation from †normal	Cloudy days Total Partial	Rainy days Total + Traces
April	+0.5	-1.01	16 8	8+3	-3.8	+0.48	20 5	14+3
May	+1.9	-1.07	18 11	8+3	-1.8	+0.38	21 11	16+4
June	-0.5	-0.42	18 11	12+4	+0.7	+0.87	18 13	17+2
July	+0.4	+0.73	16 12	9+3	+4.4	-1.25	12 10	4+3
	1902				1903			
	Temp. variation from †normal	Precipitation variation from †normal	Cloudy days Total Partial	Rainy days Total + Traces	Temp. variation from †normal	Precipitation variation from †normal	Cloudy days Total Partial	Rainy days Total + Traces
April	-2.2	-0.68	20 9	10+5	0.0	+1.26	19 7	13+4
May	+1.7	-0.48	17 11	7+4	-2.4	-0.72	14 9	8+3
June	-3.3	+3.95	19 12	14+6	-5.3	+0.11	21 11	13+4
July	+0.2	+0.78	15 11	12+1	-0.9	-0.08	15 12	7+2

* See bottom, p. 119.

† See bottom, p. 121.

TABLE II: Concluded.

	1904				1905			
	Temp. variation from †normal	Precipitation variation from †normal	Cloudy days Total Partial	Rainy days Total + Traces	Temp. variation from †normal	Precipitation variation from †normal	Cloudy days Total Partial	Rainy days Total Trace
April	-5.4	+0.66	22 8	*15+4	-1.4	+0.35	19 8	*10+5
May	-0.5	+0.16	19 9	14+5	-0.6	+2.06	19 10	15+2
June	-1.6	-1.06	17 10	10+5	-1.9	+0.75	17 9	11+3
July	-2.6	+0.22	16 11	10+4	-0.8	+0.09	19 12	12+4
	1906				1907			
	Temp. variation from †normal	Precipitation variation from †normal	Cloudy days Total Partial	Rainy days Total + Traces	Temp. variation from †normal	Precipitation variation from †normal	Cloudy days Total Partial	Rainy days Total Trace
April	+2.3	-0.96	16 8	8+3	-7.2	-0.01	22 7	14+3
May	+0.1	-1.46	18 10	9+2	-6.8	-0.20	20 10	12+3
June	+0.1	-0.53	18 12	8+5	-4.0	+0.81	17 9	15+2
July	-1.8	+1.17	17 11	15+2	-1.3	+1.40	18 13	15+4
	1908				1909			
	Temp. variation from †normal	Precipitation variation from †normal	Cloudy days Total Partial	Rainy days Total + Traces	Temp. variation from †normal	Precipitation variation from †normal	Cloudy days Total Partial	Rainy days Total Trace
April	+1.4	+0.82	18 7	13+3	-0.4	+1.3	21 11	12+3
May	+1.4	+1.22	22 12	15+6	-2.4	+1.1	19 10	12+3
June	-0.1	-1.32	13 10	10+3	+0.8	+1.9	20 12	17+0
July	+0.1	-0.02	16 11	13+4				

* See bottom, p. 119.

	Temp.	Rainfall
† 1908 Normals:	April 49.6	2.87
	May 61.4	3.50
	June 69.3	3.84
	July 73.8	4.1

RELATION OF SOIL AND FERTILITY TO THE OAT BLIGHT.

As noted in the literature quoted (see pp. 92, 93) it is quite apparent that the type of soil and the condition of its fertility have little restraint upon checking the distribution of the disease; by this it is not intended to convey the idea that well-drained and fertilized fields do not, under blight conditions, yield more and withstand the evil effects of the disease better than do poorly drained and run-down soils. The facts are that the disease is prevalent in well drained and rich soils as well as on poor and ill-drained soils; but the density of growth of the plants on the better soils tends to prevent spattering; vigorous plants resist the rapid spread of the lesions when infection does take place, and finally recover more quickly from the disease, than plants of lower vitality on weak

and poorly drained soil. Observations would seem to point to the conclusion that the bacteria which cause oat blight are probably more or less persistent soil organisms. If such is the case, it again emphasizes the need of a much greater knowledge of the bacterial flora existing within the soil, how it may be changed, and the influence of the final products upon fertility and growth. It is even possible that during seasons of excess of rain, humidity and cloudiness the bacterial flora so differs, from the normal, as to bring about very marked changes in the soil solutions. In other words, may not some of these troubles which are now spoken of as physiological, be due to detrimental products thrown off in the soil solution by a change of the bacterial flora, this change of flora being the result of a somewhat lengthy, abnormal, meteorological period. The writer is of the opinion that detrimental soil products result more probably from the work of the bacterial and fungous flora of the soil than from the excretions of higher plants.

POSSIBILITY OF THE TROUBLE BEING PHYSIOLOGICAL.

The blight occurring as it does in seasons which are somewhat abnormal would suggest the possibility of the whole trouble being what is often spoken of as physiological. Its appearance in unusual seasons, like 1907, in which the rainfall was in excess, the temperature on the whole extremely low, with now and then a bright, hot day, though as a rule cloudy weather prevailed, would suggest the possibility that these unusual weather conditions brought about an environment unsuitable for the oat crop, resulting in the peculiar yellowing and later in the collapse, so characteristic of the blight. This would suggest a trouble similar to the tip reddening, which may be brought about by a water-logged soil, or an improperly aerated root system. The writer carried out two experiments in the hope of obtaining data along these lines. These experiments were run simultaneously, one under cold or cool conditions, while the second was run under warm conditions. In both, the oats, as soon as the second blade showed, were kept excessively watered and on a part of each bed bacteria of the oat blight were placed on the roots. The results were quite different in the two experiments. The oats kept in the warm house and excessively watered showed a general tip reddening or blight from which no blight bacteria could be cultured; this condition was equal on those infected at roots and those not infected. In the oats growing under cold temperature, very little of this tip reddening could be found; and what did show, produced no bacteria when cultured. This tip reddening from excess of water and non-aeration of soil, may often be observed in

fields where much water has stood. It differs so greatly from the bacterial blight as to be quite easily distinguished. That this general (bacterial) blight is not due physiologically to non-aeration of the soil is readily seen by the conditions prevailing in the fields. As a rule the blight makes its appearance first on the higher grounds as observed by the writer in 1908 and 1909. Van Hook made similar observations in 1907 (see p. 100) and also C. J. Metcalf (see extract from letter, p. 97).

If lack of drainage was the chief factor, the lower areas should first show the blight.

It is well known that excessively low temperatures will bring about abnormal coloration of leaves; such discolorations are everywhere present following the first few cold days of fall. The extremely low average temperatures prevailing throughout the growing season of 1907 were thought to have had much to do in bringing on the unusual blight of oats that season. That such a conclusion based upon this as the chief factor will hardly hold, we discover, when we compare the temperature of the growing season of 1890 with that of 1907, in which former year the blight was much more severe. The data here follow, + = above, and - = below normal average:

	April	May	June	July
1890.....	+1.5	-1.4	+3.8	-0.2
1907.....	-7.2	-6.8	-4.0	-1.3

Since the appearance of blight in its severity is generally a matter of the weather conditions prevailing throughout the month of June, we can here readily see that the greatest blight season followed under average high temperatures.

BLIGHTS FROM HELMINTHOSPORIUM SPECIES.

Very often young oat plants show lesions of a brownish purple color, which are due to a *Helminthosporium* sp., or probably two different species. The first of these appears on seedlings, at the time when the plantlets have only two or three blades (see Fig. 1, Plate XII). This trouble in certain seasons affects many of the seedlings, sometimes as high as 16 percent (see note in description opposite Plate XII), causing a limited injury. The second *Helminthosporium* blighting is really only a spotting of the oat blades at the time when plants are six inches to 20 inches high. The spots are usually $\frac{1}{4}$ to $\frac{3}{4}$ inches long and $\frac{1}{8}$ to $\frac{1}{4}$ inches wide. Such spots cause little or no injury to the plants, and may be passed by with little concern (see Figs. 2 and 3, Plate XII).

DESCRIPTION OF PLATE IV.

Showing in the illustration at the left and center two species of grain aphides at work on oats, at the right is shown the type of injury resulting from aphid sucking; this injury differs entirely from the brown bacterial blight. The aphides here shown are free from, that is, not carrying, the bacteria which produce the blight of oats. The oat blades here illustrated were taken from the cage shown in Plate III at the time when the plants were seven weeks old. Enlarged four diameters.

3-26-09. Original.

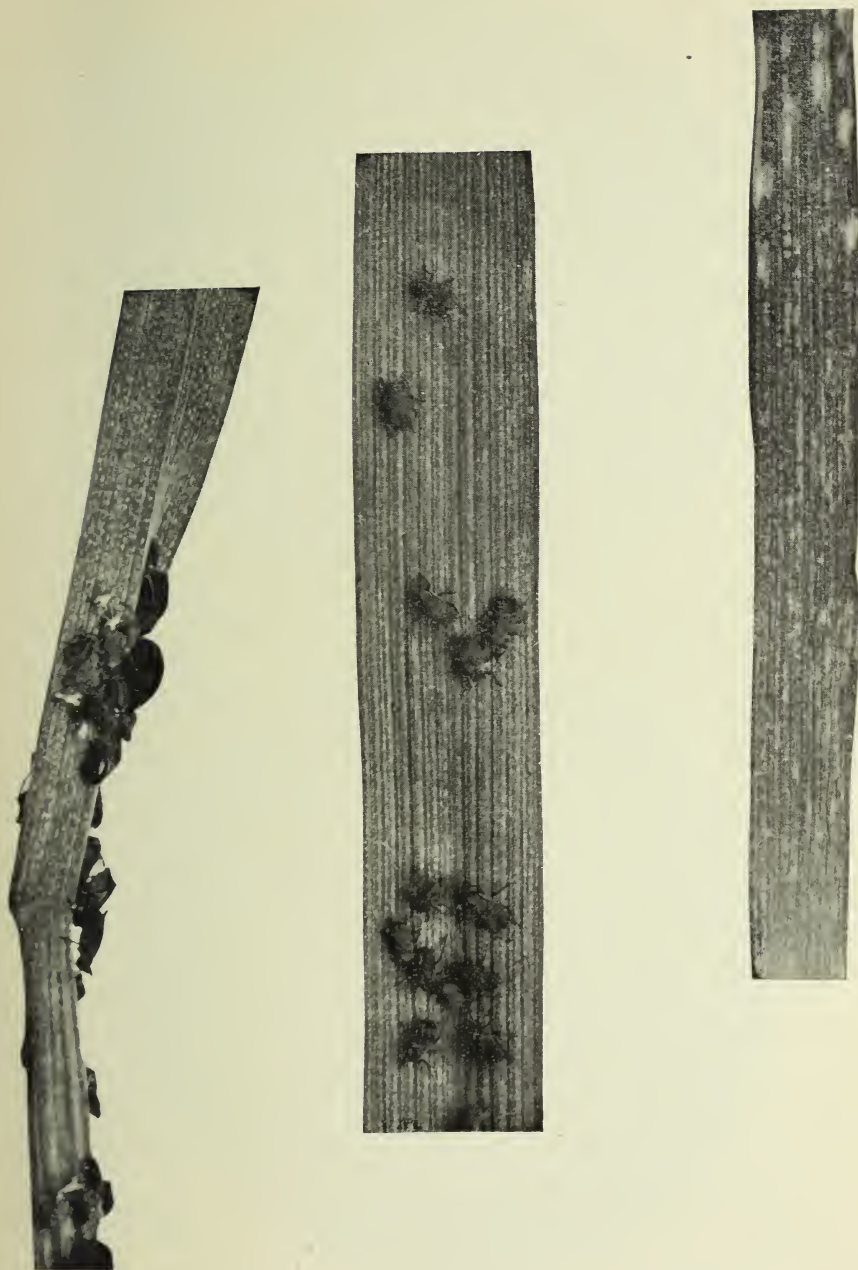


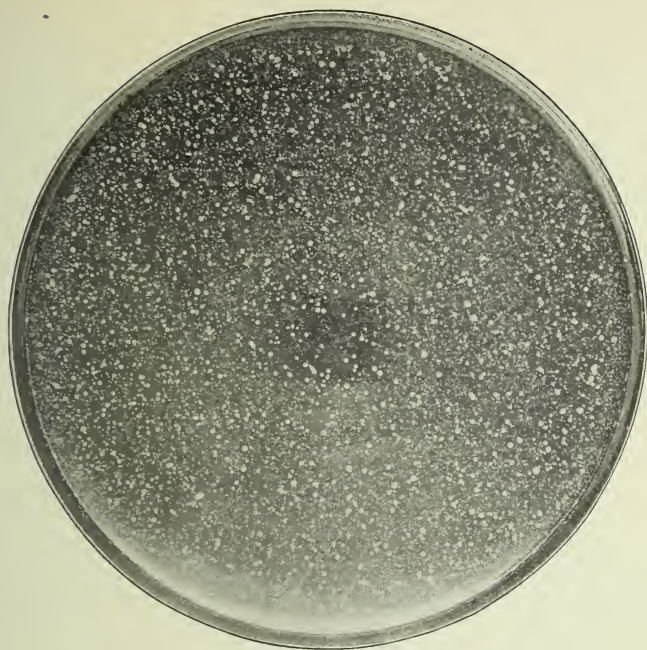
PLATE IV.

DESCRIPTION OF PLATE V.

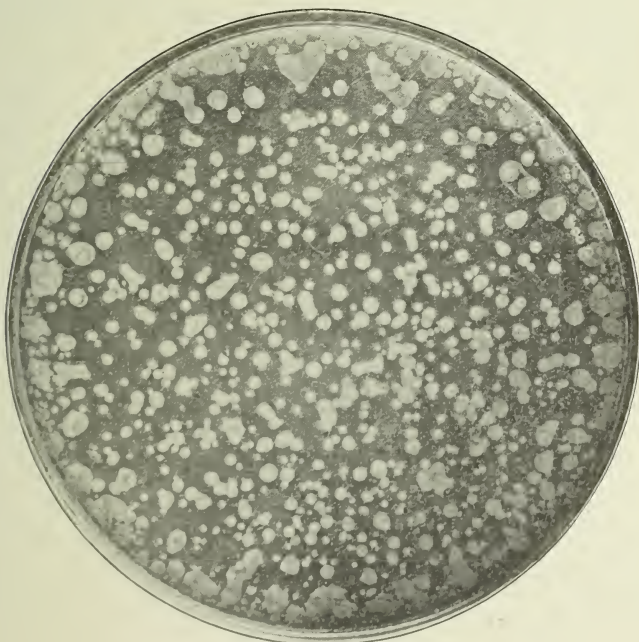
1. Showing colonies of the bacteria of oat blight taken directly from a yellowed oat blade, culture three days on nutrient glucose agar. The colonies are too much crowded to make further growth. A mixture of these organisms when inoculated into oats produced the blade blight.

2. Showing colonies of the bacteria of oat blight taken directly from a live aphid. Mixtures of these organisms when inoculated into oats gave the typical blade blight, thus showing that the grain lice carry at times viable organisms of the oat blight. Cultures three days old on nutrient glucose agar. Both plates by seven-eighths.

6-10-08. 7-13-08. Original.



1.



2.

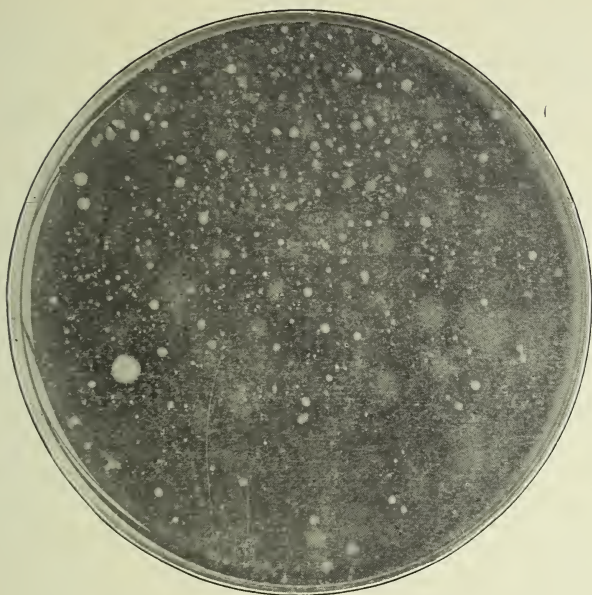
PLATE V.

DESCRIPTION OF PLATE VI.

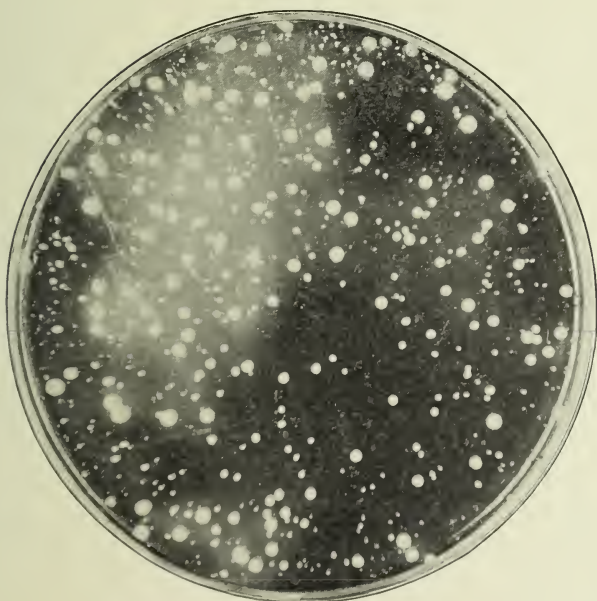
1. Showing a plate culture of the white bacterium (*Pseudomonas avenae* n. sp.) of oat blight on nutrient glucose agar, .5 percent acid to phenolphthalein, in moist chamber six days at 20° C. The graying or fogging of this medium is characteristic. The spreading of the colonies at the bottom of the plate is likewise characteristic.

2. Showing a plate culture of the yellow bacterium (*Bacillus avenae* n. sp.) of oat blight on nutrient glucose agar, .5 percent acid to phenolphthalein, in moist chamber four days at 30° C. The yellow pigment in this organism becomes more or less pronounced as the medium is changed from alkalinity to acidity. Both plates by four-fifths.

3-22-09. 3-20-09. Original.



1.



2.

PLATE VI.

Nematodes occasionally cause a yellowing in seedlings of oats followed by a dying, through their destruction of the stem or root one-half to one inch below the soil. Each of these oat troubles may be easily distinguished from the bacterial blade blight.

KINDS OF INJURY RESULTING TO OATS FROM THE BACTERIAL BLIGHT.

The different manifestations of the disease depend much upon the age and the part of the plant attacked. Observations and experiments made by the writer tend to show that the disease is most specific on the parts of the plant above ground. In the infection work carried out in the pathologium, the writer failed to produce the disease by placing the organisms on the roots. Observations in the field, though not fully substantiating the results of these experiments show however, that among seedling plants, but few become infected by way of root, or that portion of the stem which is underground. In plants beyond the seedling stage it is quite common to find the yellowing lesions following the stem and extending to the very tips of the leaves, sometimes affecting only one side of the blades, and again yellowing the middle or the whole of the blades (see Plate XIII). Just where these lesions begin is sometimes difficult to tell; often they are found beginning on the culm, but more often they originate in the blade and work backwards to the stem. There is no doubt, however, that the disease does at times start in the roots, or that part of the stem in contact with the soil. In older plants it is quite common to find the whole plant showing a general collapse of the foliage, resulting from the disease working backwards into the stem from an early infection of the lower leaves. In many cases of this kind collapse of the upper leaf-tips may occur when bacteria are not present in them; they are, however, present in the lower leaves and lower culms. The usual appearance of the disease is that of a primary yellowing of the blades, which sooner or later is changed to a mottled red and brown. This latter coloring results as the leaves collapse. Sometimes this latter stage, in extreme cases, gives the field the appearance of a severe attack of rust, described by correspondents in the phrase "as red as fire."

This bacterial blight disease is one of the causes of blast in oats. The following data show how directly proportional is the blast of oats to the amount of blade blight. These counts were made during the season of 1909, upon the several varieties of oats and barleys under varying amounts of blight, in the variety plots at the central farm of the Station at Wooster.

Variety	Amount of blade blight	Percent of kernels blasted in the head	Percent of sound kernels in the head	Yield per acre 1909
Improved Am. Oats	Average condition—little blighted	17.2	82.8	73 51
Wide Awake Oats	Average condition—considerably blighted	35.8	64.2	55 42
Wide Awake Oats	Where little blighted	12.8	87.2	.....
Wide Awake Oats	Where quite extensively blighted	22.5	77.5	.....
Wide Awake Oats	Where badly blighted	50.6	49.4	.....
Oderbrucker Barley	A v. condition—Very little blighted	6 1	93.9	37.81
Princess Barley	A v. condition—Noticeable though not bad	28.8	71.2	24.64
Primus Barley	A v. condition—Bad, generally blighted	70.8	29.2	9.01

Observations this season (1909) supported by culture work, show that the heads may be partly or wholly blasted by lesions coming in contact with them. These lesions often begin on the flag leaf and work downward, affecting the head differently, according to its maturity (see Plate XIV), that is, heads entirely covered in sick sheaths are so blasted that they fail to push out at all; others which are just ready to push out at the time when the sheaths become affected, will show more or less blasted kernels. Often the head is halfway out before any part of it comes in contact with the sick sheath, in which case the lower half of the panicle becomes blasted.

The greatest loss to oats from the bacterial blight is due to the injury and collapse of the blades, causing a lowered vitality, with an increase of blast. This injury results, as a rule, from primary infection through the stomata of the sheaths and blades. A smaller loss results from a direct blasting of the heads, due to sheath lesions coming in contact with them. It is also very probable that such specific bacteria, when present in the soil, give rise to products which are detrimental to the oat crop. Just what consequences would result to oats growing in a soil medium filled with such specific organisms as the oat blight bacteria, would be difficult to predict. If the specific lesions in oats result from the effect of a toxin or a destructive enzyme produced by the blight bacteria, then, were these organisms abundant in the soil, it would be reasonable to suppose that the oats would suffer from taking up their specific products. Such may be the very conditions which are actually taking place in those fields showing blight for several seasons successively. This is a phase of soil investigation which should certainly be covered, that is, whether an abundance of these specific organisms in the soil plays a detrimental role against the growth and maturity of oats. *That there is a specific abnormal condition of the oat crop*, is evident from the many observations noted in

the literature quoted. This diseased condition is worse in certain localities than in others, and varies even in fields but little affected. There seems to be some evidence which indicates that these blight organisms in certain small areas, in fields showing limited infection, bring about a condition in the soil which is objectionable to the growing oat plant; if such is the case these areas may be called "oat-sick."

STUDIES IN LIMITING THE ORGANISMS OF OAT BLIGHT.

The field observations noted, and the cultural work herein covered, extend over a period of the past two years. The observations in the field include those of the two growing seasons of 1908 and 1909, supplemented by the observations made by Prof. Selby and his assistant, J. M. Van Hook, in 1907. The artificial inoculations have been run on six different occasions for periods varying from three weeks to three months, under varying weather conditions. The results all point to the same conclusion, namely, that the disease is caused by the symbiotic relation of two bacteria. During the season of 1908 artificial inoculations in oats in field plots conclusively showed that the yellow organism (*Bacillus avenae*) did not produce lesions, and that the white organism (*Ps. avenae*) would produce but very limited lesions, but when a mixture of these organisms, made directly from crushed leaves, was inoculated, the lesions spread rapidly. This same line of work, duplicated in the pathologium under varying moisture and temperature, gave under favorable conditions exact duplicate of the field work. No typical blight resulted unless both organisms were inoculated into the same plant, conclusively showing the above deductions. The white organisms (*Ps. avenae*) when inoculated alone produced a limited lesion which was light in color and not typical of the lesions of oat blight; since the yellow organism (*B. avenae*) when inoculated alone failed to produce any lesion at all or to make any signs of headway, the active agent in the production of the pathogenicity is *Ps. avenae*. The relation of the yellow organism to the spread of the lesion seems to be that of maintaining a proper nidus for a virulent growth and production of the active toxin or enzyme by the white organism.

A series of plate cultures, run for the purpose of determining the rate of distribution of the organisms throughout the leaf, tends to show that the lesion when the yellow organism is present spreads even more rapidly than do the organisms. That is, yellowing which extended clear to the ends of the leaves often failed to show the yellow organism at all when cultures of the tips were run, and in many instances would show only a few colonies of the white organisms (*Ps. avenae*). In the case where the white organism was

inoculated alone this relation of the bacteria to the spread of the lesion was entirely different, the lesion extending only the distance of the spread of the organism. This line of work would seem to show that the association of the two organisms results in a much more rapid production and spread of the toxin or other products which cause the breakdown of the chlorophyl or the destruction of the cellular work of the leaves. This series of culture work was carried out as follows: Leaves which showed yellowing six to nine inches from the point of inoculation were placed in cultures, using a one-half inch section of the leaf one inch distant from the point of inoculation, and another section six to nine inches from the point of inoculation. In all the plates made from the sections one inch from the point of inoculation, both the yellow and white organisms were found in abundance, while in those plates made from the tip sections of the leaves at a distance of six to nine inches from the point of inoculation, in many there was little or no evidence of the yellow organism and in several of the plates no colonies of the white organism, showing that the lesions are some times more extended than the bacteria.

CHARACTERISTICS OF THE WHITE BACTERIUM OF OAT BLIGHT.

Pseudomonas avenae n. sp.

Following Migula's classification and the numerical system* this organism becomes Ps. 111.2223032.

MORPHOLOGY.

This organism, taken from 24 hour cultures on any of the ordinary culture media, is a bacterium of short, rod shape with round ends, and with few internal markings, having a diameter of .5 to 1 micromillimeter and a length of 1 to 2 mm. The majority of the organisms measure about $\frac{3}{4}$ mm. in diameter, having a length of 1.5 mm. In hanging drop the flagellate individuals are actively motile, though being limited in number even in the most viable cultures. Occasionally in plates of nutrient agar and in old nutrient glucose agar cultures, the organisms are much shorter, assuming oval or nearly coccus forms. In agar-hanging-block-mounts the organisms separate quickly upon division, very seldom being found in chains of three or four.

Staining Reactions: The organism does not retain Gram's stain.

Endospores: Bodies which are apparently endospores are found in old cultures of the organisms such as those which have run for one month or more. When mounts of such cultures are made, especially those from nutrient glucose agar, and stained with hot carbolfuchsin for three or four minutes, these bodies retain the stain similar to spores. (See Fig. 2, Plate IX). In type, they are

*See Descriptive Chart, endorsed by the Society of American Bacteriologists, December 1907.

similar to the spores found in the anthrax organism, *Bacillus anthracis*. When stained with hot carbolfuchsin they may be decolorized for a few seconds with 5 percent sulphuric acid without losing the stain. Observations were not made as to the growth from these bodies, though cultures which had run nine months before transferring and which had dried up, produced a growth of the white organism, tending further to show that the organism is carried over by more than the vegetative form. Clostridium forms may be observed in nutrient glucose agar in one week old cultures.

Staining for Flagella:

This organism is very difficult to stain in demonstration of the flagella. The film on cover slip appears to fix poorly and in many attempts the film loosens. This is especially true in the use of Van Ermengem's stain, but not so marked in the use of Pitfield's or Muir's modification of Pitfield's. In the use of the two latter stains, though the film holds fairly well, it is found upon examination that the flagella are delicately stained and also very scarce unless one is fortunate in fixing and

equally so in catching the



Fig. 1. *Pseudomonas avenae* n. sp. The bacterium which is the active agent in the cause of oat blight. Culture three days on nutrient glucose agar. Drawn from Van Ermengem's stain.

growth before the flagella have been cast off. Much difficulty is met with in attempting to limit the number of flagella. In general only one polar flagellum is present. After a careful study of a number of slides, covering over a month's work on staining, the writer has concluded that there is found occasionally individuals having two or three polar flagella, but these are very few (see Fig. 1. p. 134). The cultures have been carried out in triplicate, using the organism from different sources and the work being run at different periods of time. This work on limiting the organism through cultures began in January 1909, and continued through June.

CULTURAL CHARACTERISTICS.

Plate work: Little difficulty is met with in obtaining the two organisms of oat blight as a mixture from the sick blades. The writer sterilized the blades externally with a solution of corrosive sublimate made with two grams of bichloride of mercury in 1000 cc. of equal parts of commercial alcohol and water. The leaves were placed in this solution for one to one and one-half minutes and were then quickly followed by four washings with sterile water. This disinfection in no way apparently injured the organisms which were internal, but proved very efficient in destroying surface contaminations. When mixed the two organisms make a medium to rapid growth and in two to three days they can be plainly seen. Sometimes the yellow organism predominates, but as a rule the white bacterium, when growth takes place properly, is the predominating organism in numbers, though the yellow organism is always the first visible and in some instances, when the medium is slightly unfavorable to the white organism, it may in growth overwhelm the latter. Medium that has become too much dried out is very unfavorable for the white organism (*Ps. avenae*). The growth of the white organism as a whole, when taken in pure culture, is somewhat feeble on the ordinary artificial media, and a number of transfers seem to reduce its viability greatly, so that in many instances it fails altogether to make growth. The culture media most suitable for continued growth appear to be nutrient glucose agar and nutrient saccharose agar.

Agar stroke: Growth very slow, usually visible in three or four days, scanty to moderate, filiform, rather flat, glistening, with margin smooth, opaque to opalescent, non-chromogenic, with little or no odor, having a slimy consistency. The medium, as a rule is turned slightly gray.

Potato plug: Growth moderate, spreading, at first glistening, later dull, smooth, non-chromogenic, no odor, of a slimy consistency.

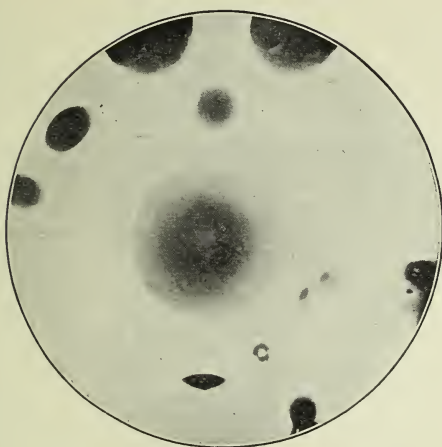
Agar stab: Growth best at the top, though very thin, white and widespread. Line of puncture filiform, slightly beaded near top, growth soon limited in the deeper medium.

Gelatine stab: The line of puncture becomes visible about the third day. Growth is best at the top and is somewhat limited along the stab, the line of puncture is filiform and slightly papillate. Liquefaction is crateriform and begins in seven to twelve days. In two weeks liquefaction has covered about the upper one-third of a two inch culture (see Fig. 2, Plate VIII); in sixty days the liquefaction is complete. The precipitate is a grayish light yellow.

Nutrient broth: Visible growth is present in three days. Medium slowly clouds with no flocci or pellicle, clouding moderate and persistent, odor resembling decay by *B. subtilis*, Sediment scant but compact, very light yellow.

DESCRIPTION OF PLATE VII.

1. Showing a surface colony of the white bacterium (*Pseudomonas avenae* n. sp.) of the oat blight in nutrient glucose agar culture; six days at 22° to 23° C. Enlarged seven and one-half times.
2. Showing a sub-colony of the white bacterium of oat blight in nutrient glucose agar plate culture; six days in moist chamber at 22° to 23° C. Enlarged 65 times.
3. Showing sub-colony of the white bacterium of oat blight differing somewhat in shape from the colony illustrated in (2) above. In nutrient glucose agar plate culture; six days at 22° to 23° C. Enlarged 65 times.
4. Showing a sub-colony of the yellow bacterium (*Bacillus avenae* n. sp.) of oat blight in nutrient glucose agar plate culture; four days at 22° to 23° C. Enlarged 65 times. (All taken 5-18-09). Original.



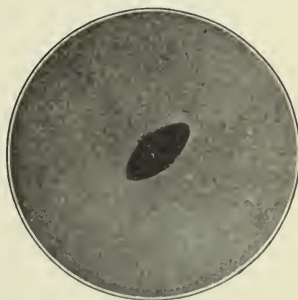
1.



2.



3.



4.

DESCRIPTION OF PLATE VIII.

1. Showing a gelatine stab culture of the white bacterium (*Pseudomonas avenae* n. sp.) of oat blight one week old; temperature 22° to 23° C. (Medium .5 percent acid to phenolphthalein). Natural size. 3-30-09.

2. Showing a gelatine stab culture of the white bacterium (*Pseudomonas avenae* n. sp.) of oat blight two weeks old; temperature 22° to 23° C. (Medium .5 percent acid to phenolphthalein). Natural size. 4-6-09.

3. Showing nutrient glucose agar (.5 percent acid to phenolphthalein) slant culture of the white bacterium (*Pseudomonas avenae* n. sp.) of oat blight, temperature 22° to 23° C.; two weeks old. 3-21-09.

4. Showing a gelatine stab culture of the yellow bacterium (*Bacillus avenae* n. sp.) of oat blight two weeks old in medium .5 percent acid to phenolphthalein. Temperature 22° to 23° C. 3-30-09.

5. Showing a potato plug culture of the yellow bacterium, (*Bacillus avenae* n. sp.) of oat blight, two weeks old at temperature 22° to 23° C. 3-27-09.

6. Showing nutrient glucose agar (1.5 percent acid to phenolphthalein) slant culture of the yellow bacterium (*Bacillus avenae* n. sp.) of oat blight; one week old at temperature 22° to 23° C. 3-19-09. All original. Natural size.



1



2



3



4



5



6

Milk: No coagulation in thirty days. The reaction is slightly acid and apparently remains so.

Litmus milk: Beginning with the second day the medium shows a very slight acidity which gradually increases up till the 10th day, after which the acidity begins to weaken; no coagulation.

Gelatin colonies: The growth is somewhat slow, colonies becoming visible about the second to the third day. At the end of the 7th day pitting is noticeable. The colonies at three days are white to gray, round, with margins entire; in two to three weeks the pitted colonies become confluent and liquify this medium.

Agar colonies: Growth is very slow; colonies are visible about the third day. Colonies round with smooth surface and edges entire. The internal structure is amorphous, somewhat more dense at center.

Growth: Growth takes place best on nutrient glucose and saccharose agar.

PHYSICAL AND BIOCHEMICAL FEATURES.

Gas and acid production: No gas is produced in the following sugar bouillons: dextrose, saccharose, lactose, maltose and glycerin. Little or no growth takes place in the closed arm of the fermentation tube. The production or change in acidity in each of the above media is as follows. Dextrose, check 1.5 percent acid to phenolphthalein; first day's growth 1.25 percent, second day's growth 2. percent, fourth day's growth 1.82 percent. Saccharose bouillon, check 1.9 percent acid; growth shows no change in four days. Lactose, check, 1.75 percent acid; first day's 1.37 percent, second day's 1.75 percent, fourth day's 1.25 percent. Maltose bouillon, check, 1.87 percent acid; first day's growth 2.25 percent, second day's 1.75 percent, fourth day's 1.57 percent. Glycerin, check, 1.5 percent acid; first day's growth 1.42 percent, second day's 2. percent, fourth day's 1.51 percent acid. These variations are very slight and the conclusions would seem to be that the white organism, *Ps. avenae*, produces but very little change in the reaction of media.

Ammonia: None produced.

Nitrates: Reduced to nitrites in nitrate bouillon.

Indol: No indol is produced,

Tolerations of acids and alkalies: This organism is very sensitive to alkalies, producing only limited growth in .5 percent alkaline medium (to phenolphthalein), and likewise on the other hand it is quite sensitive to acids, making but little growth on medium beyond 1.5 percent acid to phenolphthalein. The optimum reaction for growth appears to be about +10 in Fuller's scale.

Vitality on media: When grown on nutrient glucose agar, and nutrient saccharose agar, the vitality of this organism is quite pro-

longed. Its life on culture media appears to be a matter of spore production, which latter apparently form after several weeks on sugar media.

The thermal death point in young cultures is reached in a ten-minute exposure at 60° C.

The optimum temperature for growth is between 20° and 30° C.

Light is very active in checking the viability of this organism.

Drying quickly kills the organism in young culture, though in old cultures the spores apparently carry it over.

Effects of germicides: This organism in the vegetative state is much more susceptible to germicides, heat, light and drying than is the yellow organism. Killing results in ten minutes in a 1 in 15,000 solution of corrosive sublimate, or 1 in 7,500 of formaldehyde. In a toleration test in nutrient glucose bouillon having one gram of corrosive sublimate in 75,000 cc. and when 1 cc. of formaldehyde in 15,000 cc. was used, the organism failed to grow.

Pathogenicity: Pathogenic in blades of oats (*Avena sativa*), corn (*Zea mays*), timothy (*Phleum pratense*), barley (*Hordeum distichum*), wheat (*Triticum vulgare*), and in the culms and sheaths of the blue grasses (*Poa pratense* and *P. compressa*).

DESCRIPTION AND CHARACTERISTICS OF THE YELLOW BACTERIUM OF OAT BLIGHT.

Bacillus avenae n. sp.

Following Migula's classification and the numerical system* this organism becomes B. 222.2223532.

MORPHOLOGY.

This organism when grown on nutrient glucose agar at room temperature 22° to 23° C., for twenty-four hours is a very actively motile bacillus of short, rod shape with rounded ends, measuring from .75 to 1 x 1.5 to 2 micromillimeters. The majority are about .75 mm. x 1.7 mm. Division when observed in agar hanging block takes place quickly, the organisms soon separating; usually found singly, but some times observed in short chains of three or four.

Staining reactions: This organism does not retain Gram's stain.

Endospores: No endospores have been observed.

Flagella: The flagella are many, peritrichiate, long, undulate; easily stained with Pitfield's or Van Ermengem's method.

CULTURAL FEATURES.

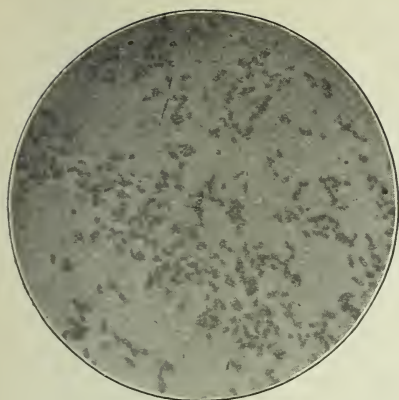
Agar stroke: Growth is very rapid and abundant. Filiform, slightly raised, at first white, glistening, later turning somewhat dull, margin smooth, growth rather opaque; the third day turning yellow; growth somewhat mucous: no noticeable odor.

Potato: Growth abundant and persistent, rapidly spreading; diffuse, dull, margin smooth; pigment yellow. Consistency mucous. No characteristic odor.

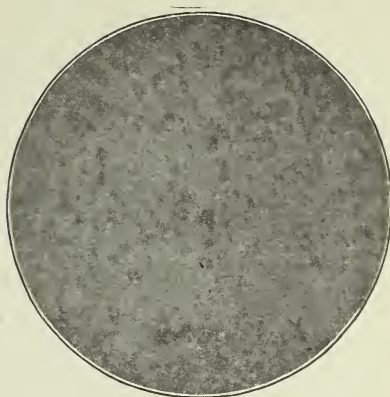
*See footnote p. 133.

DESCRIPTION OF PLATE IX.

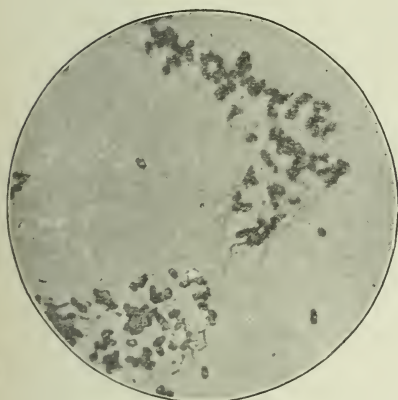
1. Showing the white bacterium (*Pseudomonas avenae* n. sp.) of oat blight from nutrient glucos agar plate, ten days in moist chamber. Carbolfuchsin. Enlarged 1000 times. 4-3-09.
2. Showing what appear to be spores of the white bacterium (*Pseudomonas avenae* n. sp.) of oat blight from a two months old culture on nutrient glucose agar stained with hot carbolfuchsin four minutes and decolorized with 5 percent sulphuric acid. Enlarged 1000 times. 5-17-09.
3. Showing polar flagella of the white bacterium (*Pseudomonas avenae* n. sp.) of oat blight from a twenty-four hour culture on nutrient glucose agar. Pitfield's stain. Enlarged 1000 times. 5-19-09.
4. Showing polar flagella of the white bacterium (*Pseudomonas avenae* n. sp.) of oat blight from a twenty-four hour nutrient glucose agar slant. Pitfield's stain. Enlarged 2000 times. 5-18-09.
5. Showing flagella of the yellow bacterium (*Bacillus avenae* n. sp.) of oat blight from a four days old culture on nutrient glucose agar. Van Ermengem's stain. Enlarged 1000 times. 4-3-09.
6. Showing the yellow bacterium (*Bacillus avenae* n. sp.) of oat blight; culture one week old on nutrient glucose agar. Carbolfuchsin stain. Enlarged 1000 times. 4-26-09. All original.



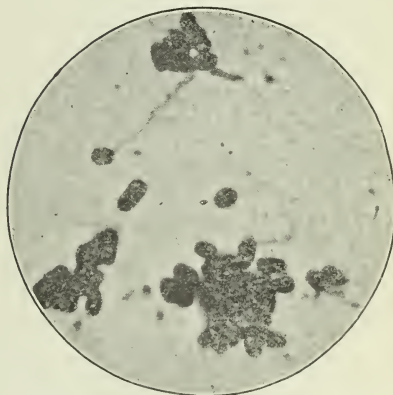
1



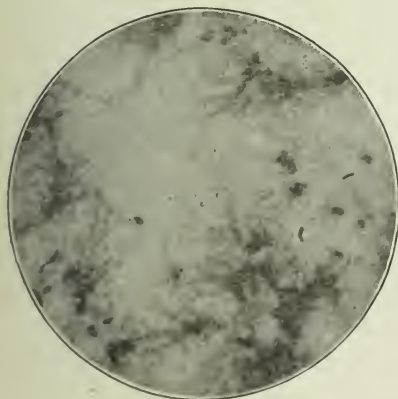
2



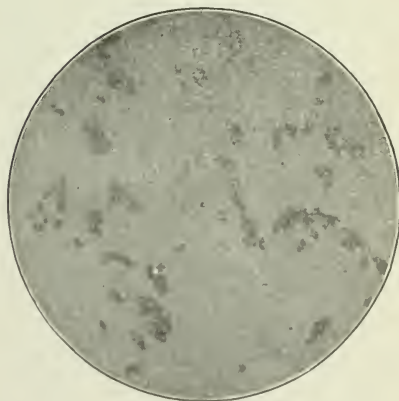
3



4



5



6

DESCRIPTION OF PLATE X.

Showing an oat plant infected with a mixture of artificial cultures of the bacteria (*Ps. avenae* n. sp. and *B. avenae* n. sp.) which cause the brown blade blight of oats; inoculated by means of a hypodermic needle at the points marked "A." The preliminary results of the infection is a yellowing extending rapidly to the very tips of the leaves; should a day or so of hot sunshiny weather follow this yellowing, the leaves will quickly assume the characteristic reddish brown color typical of the blight which results in an almost total collapse of the infected leaves. Infection had run two weeks at the time of photographing. Water colored. Natural size. 3-31-09. Original.



Agar stab. Growth best at top with an abundant growth at surface. Line of puncture filiform, slightly beaded; growth soon becomes yellow.

Gelatin stab: Growth best at top, filiform and somewhat beaded on upper line of puncture. No liquefaction takes place in four weeks. Growth turns yellow on the third day.

Nutrient bouillon: Medium becomes unevenly cloudy in twenty-four hours. The second day shows a heavy yellow precipitate.

Milk: Coagulation shows at the end of two weeks at which time extrusion of whey begins. The reaction of check was 1.57 percent acid to phenolphthalein. At the end of the second day's growth the reaction was 1.95 percent acid; at the end of the fourth day's growth the acidity was 2 percent. The general consistency of the milk remained apparently unchanged until the end of the second week, when coagulation set in.

Litmus milk: Shows acid at the end of the first day and gradually becomes more marked until the fourth week. Coagulation takes place the second week.

Gelatin colonies: Growth is very rapid; colonies visible in twenty-four hours. Round and slightly raised, edge entire; no pitting or liquefaction. Sub-colonies lenticular.

Agar colonies: Growth is rapid at room temperature; round, with smooth surface, slightly raised; edges entire. Amorphous somewhat denser at center. Sub-colonies lenticular, amorphous though center dense.

Growth: Growth takes place best on nutrient glucose or saccharose agar.

PHYSICAL AND BIOCHEMICAL FEATURES.

Gas and acid production: No gas is produced in the following bouillons: dextrose, saccharose, lactose, maltose and glycerin. Growth is noticeable in the arm of fermentation tube in the dextrose and saccharose, though not marked. There is possibly a slight growth in the closed arm in lactose and glycerin. The production of acid in each of the above media takes place as follows: Dextrose, check, 1.5 percent acid to phenolphthalein, first day's growth 3.8 percent, second day's growth 3.8 percent, fourth day's growth 3.8 percent. Saccharose, check, 1.9 percent, first day's growth 3.2 percent, second day's growth 3.5 percent, third day's growth 3.4 percent. Lactose, check, 1.7 percent, first day's growth 1.7 percent, second day's growth 1.9 percent, fourth day's growth 2 percent. Maltose, check, 1.8 percent, first day's growth 2.5 percent, second day's growth 3 percent, fourth day's growth 3 percent. Glycerin, check, 1.5 percent, first day's growth 1.9 percent, second day's growth 2.2 percent, fourth day's growth 2.2 percent.

Ammonia: No ammonia is produced in nutrient bouillon or in nutrient sugar bouillon.

Indol: Production of indol is moderate in sugar free bouillon.

Nitrate reduction: Nitrates are reduced to nitrites in nitrate broth.

Toleration of acids and alkalis: This organism makes fair growth in 2.5 percent acid medium to phenolphthalein while 1 percent alkaline medium retards its growth.

Optimum reaction for growth in nutrient sugar bouillon or nutrient sugar agar is +15 in Fuller's scale.

Vitality on culture media is long.

The thermal death point is reached in a ten minute exposure at 60° C. The optimum temperature for growth is between 20° and 30° C. Very resistant to exposure in light.

The organism is quite resistant to drying in cultures.

Effects of germicides: Killing results in ten minutes in a one in 10,000 solution of corrosive sublimate or in a one in 5,000 solution of formaldehyde. In a toleration test in nutrient glucose bouillon, growth failed in this medium having one gram of corrosive sublimate in 50,000 cc., and likewise when 1 cc. of formaldehyde in 10,000 was used.

Pathogenicity: The organism is not pathogenic by itself; however, in symbiotic relation with *Pseudomonas avenae* n. sp., it aids in producing the blade blight of oats.

THE POSSIBILITY OF SELECTING RESISTANT STRAINS OF OATS.

A casual examination of different oat varieties at the time when the disease is at its worst would seem to indicate little possibility of selecting a variety having much resistance. However, such a conclusion does not seem to be sustained when yields are considered. The results from the variety oat test at this Station for the season of 1907 (the heavy blight year) gave for the Sixty-Day variety a yield of 56.95 bushels as compared with 54.49, 51.13, 50.63 bushels for the three next higher yielding varieties and with 44.75 bushels for the average of all varieties excluding the Sixty-Day. Van Hook in his correspondence (see p. 100) notes that there existed differences in resistance to the blight disease in the oat varieties being compared here in 1907.

In 1908, the outbreak at this Station was at first most severe among the earliest sowings (some sowings of the early and late test) which were located at the south of the tier including the variety tests. Later, however, the disease appeared to be somewhat general, though not severe, on most of the varieties, appearing to be somewhat more pronounced upon Wideawake.

In the infection work in the pathologium from February to May, 1909, two varieties, viz., Improved American and Wideawake, were used respectively in the different inoculations, and it was quite

noticeable that Improved American was slower on an average to show infection than was Wideawake. Again it was noticeable that a few individuals showed marked difference in resistance from the average. It is from these individuals rather than from any special variety that the writer believes the more valuable resistant selections may come. On the other hand, there is little doubt but that the variety which shows the most resistance will also offer the greatest number of individuals for selection. Observations made this season (1909) indicate that there is some difference in susceptibility to the blight disease as manifested by the amount of infection showing on the different varieties in the test plots at the Station. The strain selected and grown as a winter oat showed no sign of blight this season, as far as the writer could determine. This same strain, when sown as a spring oat, showed but the slightest trace of the disease. On the other hand, Wideawake and several of the other varieties showed a marked beginning of infection at one time. The disease made little or no headway after the advent of sunshiny, dry weather, thus preventing further observations on the spread of the disease, and the resistance of varieties. The writer is fully satisfied that there is a good opportunity for selecting resistant strains which would quite easily overcome much of the losses from this disease.

The following data show the yields of Improved American compared with Wideawake and the average of all varieties grown in the variety oat test at this Station during the past six years²¹.

	1904	1905	1906	1907	1908	†1909
Improved American.....	85.66	59.45	87.21	45.47	67.18	73.51
Wideawake.....	77.26	56.65	73.02	40.20	50.19	55.42
Average of all varieties...	77.75	59.16	77.90	45.25	62.02	65.81

In each of the above years it is apparent that the Improved American variety outyielded Wideawake considerably, also that the average of all varieties exceeds Wideawake in yield. Some of this difference in yield between other varieties and the Wideawake is undoubtedly due to the latter's non-resistance to the blight disease.

BREEDING OF RESISTANT STRAINS AN IMPORTANT PHASE OF EXPERIMENT STATION WORK.

The writer is an ardent believer in the "ounce of prevention" theory. There are, however, two ways in which the agriculturist may considerably ward off plant diseases; one is to be continually on the alert and apply proper treatment at the right time. Should he, however, be trying to grow varieties which are very susceptible to disease, this method is not always the most pleasant and most practical.

²¹ Cir. 88, Ohio Agric. Exp't. Sta., Feb. 15, 1909, C. G. Williams.

†From data of 1909 yields furnished by C. G. Williams.

DESCRIPTION OF PLATE XI.

Showing the oat blight resulting from aphides carrying the disease. The two leaves at the left came from the check row, which became infected through the grain lice carrying the disease from the infected row. (See Plate II and the description). The lice were placed on the infected plants of the inoculated row; both rows were then caged in; in two weeks these insects had carried the disease to the check (healthy) row with the bacterial blight resulting as photographed in the two leaves at the left. The leaf at the right came from the cage in which the aphides free from the bacterial blight disease were confined (see Plate III and the description). The injuries resulting to oats from the sucking of aphides is entirely different from the blade blight. (See Plate IV). 3-31-09. Original. Natural size



A second means is to secure varieties which are known to be very resistant to the more common diseases. To accomplish the end in view both of these means: resistant varieties and treatment, should be diligently looked after. The value of using resistant varieties or strains is everywhere apparent. Take for example the loose smut of wheat in this state. Observations and examinations show that this disease is causing losses in different fields from less than .01 percent to as high as 5 percent. That such a heavy loss as 5 percent or even 2 percent is simply a matter of unwisely continuing the use of a susceptible variety is very evident. During the season of 1908, the varieties of wheat grown at this Station were carefully counted to estimate the percent of loose smut. Only seven varieties out of some forty-seven showed a loss of over 1 percent due to this disease. Among these seven are to be noted the following: Pride of Genesee 1.08 percent, Prosperity 6.47 percent, American Bronze 5.14 percent, Invincible 5.20 percent, Hickman 1.02 percent, Golden Bronze 1.87 percent, and Dawson's Golden Chaff 1.75 percent. Of the remaining forty varieties, thirty showed less than .5 percent loss from loose smut, and of these thirty, fifteen showed .05 percent or less; five showing practically no loose smut. Among those that show little or no loose smut were some of the best yielders. It is observed that these susceptible varieties show more or less smut every season. During 1908 the writer attempted to infect with loose smut the variety of wheat known as Poole. The result was negative owing to this variety's resistant qualities to the smut disease. The same is true also of oats, barley, flax, potatoes and many other crops in relation to their specific fungous diseases. Some have considerable resistance to plant diseases, possessing also good quality and high yielding capacity.

The time is now ripe when systematic selection of strains from different varieties for resistance to prevalent plant diseases may be made a great economic factor in modern production. The question so often raised, why not let nature have her course and we continually select the most prolific among the survivals, is answered by the remark that nature is much too slow for our generation, also the layman not having the knowledge of conditions favoring and limiting plant diseases, is not in line to control nature; when nature does afford the opportunity he is too deeply concerned in other lines to take advantage of it. Diseases are periodic, that is, they make their appearances irregularly according to whether meteorological conditions are favorable or not; along with favorable conditions must be present not only particular means of infection, that is, the spores or other propagating parts of the disease, but also the host. If nature were regular in her seasons, and similar in her corresponding periods, then the matter of breeding for resistant strains would

be simplified. At present, however, to accomplish ends too difficult for the layman, requires the training of the pathologist. That is, the pathologist having the specific infecting material at hand and knowing the necessary environment for the development of the disease, may and can maintain these, and subject the plant to such each year, instead of waiting for those years having the periodical outbreak of the required disease. The meteorological requirements of certain diseases are now so well known that it is quite possible to keep these diseases active in unfavorable seasons, simply by supplying the necessary conditions. This was readily shown in working with the oat blight in the pathologium during the past winter. Conditions which were unfavorable for the development of the disease were overcome by maintaining a partial shading and a saturated atmosphere.

SOME OF THE NEEDS AND POSSIBILITIES OF SELECTION FOR DISEASE RESISTANT PLANTS.

Work under glass: That the pathologium or properly regulated greenhouse can be of great use in the preliminary testing and selection of resistant strains is very evident to the writer, he having previously made use of such means in testing flax as to its resistant qualities to the flax wilt disease*. For special work of this kind, however, a greenhouse is required with apartments which permit of auto-regulation in ventilation, heating, lighting and moisture. A system which permits such regulation in heating and ventilation is not difficult to install. Likewise moisture conditions may be more or less easily controlled. Even lighting permits partial control. The great advantage of such greenhouse work is evident when with certain plants we can make time in multiplying individuals by growing and maturing an extra crop during the winter, permitting inoculation under favorable conditions for disease production, thus readily distinguishing resistant from non-resistant individuals. Such conveniences would not only give opportunity for preliminary selection, but also the means for testing out supposed resistant individuals, which under field conditions may strike the proper conditions for a test but once in two to five years. Where we start from individual plants and have no further means than nature to bring about proper meteorological conditions for the disease, sometimes we are much disappointed after carrying a good yielding plant several years, to find that it succumbs upon the appearance of certain fungous or bacterial diseases.

* "Fungi of Flax-sick Soil and Flax Seed," 1902-1904. Submitted to the North Dakota Agricultural College, Department of Botany, Feb. 1, 1909, for publication.

SOME OF THE LINES ALONG WHICH FURTHER STUDY
SHOULD BE MADE ON THE OAT BLIGHT.

The writer is fully convinced that this bacterial blight is the means of bringing about an abnormal condition of the oat crop throughout the eastern and central states. The observations and investigations herein recorded cover but a few phases in the study of this very general and important trouble.

Some suggestions pointing to investigations which would further make clear the relation between the oat blight and the specific organisms which are the cause of this disease, and economic means for the control would not be out of place at this time. Among the more important questions to be settled are the following:

1. Are these specific oat blight organisms common and persistent in soils?
2. If so, do they give rise within the soil to products which are injurious to oats and other crops?
3. If so, are these products easily or difficultly destroyed?
4. To what extent are these blight organisms within the soil responsible for the weakened vitality so conspicuous in oats?
5. What relation exists between blight and blast in oats?
6. In what types of soil and under what meteorological conditions do these blight organisms thrive best?
7. Can this blight trouble be overcome by the selection and breeding of resistant varieties?

DESCRIPTION OF PLATE XII.

1. Showing oat seedlings affected with the Helminthosporium blight. On some of the variety plots of the Experiment Station the affected plants reached 16 percent. The plants, as a rule, quickly outgrow this blight. Enlarged one and one-eighth times. 5-10-09.

2. Showing nutrient glucose agar plate culture of pieces of oat blades infected with the Helminthosporium blight. Observe the fungus coming from the pieces of oats. The soil upon which these oats grew was treated very heavily with a solution of 1 pound of formaldehyde to 20 gallons of water, using one gallon per square foot. The oats were also thoroughly treated with a solution of formaldehyde made with 1 pound to 40 gallons. These treatments either failed to kill the fungus in the soil or on the surface of the seed, or the fungus is internal. Following the above treatment on the variety, Improved American, 9 percent of the seedlings showed infection with this blight. The Wideawake variety showed nearly 11 percent of the seedlings infected. 2-26-09.

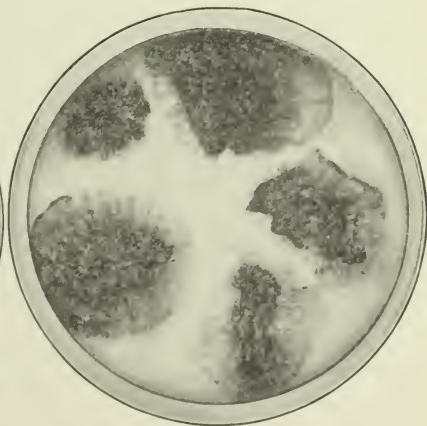
3. Showing the under surface of nutrient glucose agar plate cultures of the Helminthosporium fungus coming from pieces of infected oat blades. The sub-medium growth of this fungus assumes a very dark color as illustrated. The aerial mycelium, however, has a gray color. Plates by one-half 3-15-09. All original.



1



2



3

DESCRIPTION OF PLATE XIII.

Showing a photograph of three oat blades in different stages of the bacterial blight (from natural infection) which has in no way been complicated with the work of aphides.

1. Showing preliminary lesions (the larger, light, oval spots) from stomatic infection, spread by rains. The smaller dark spots are caused by a fungus, *Helminthosporium avenae sativae* (Briosi and Cavara).

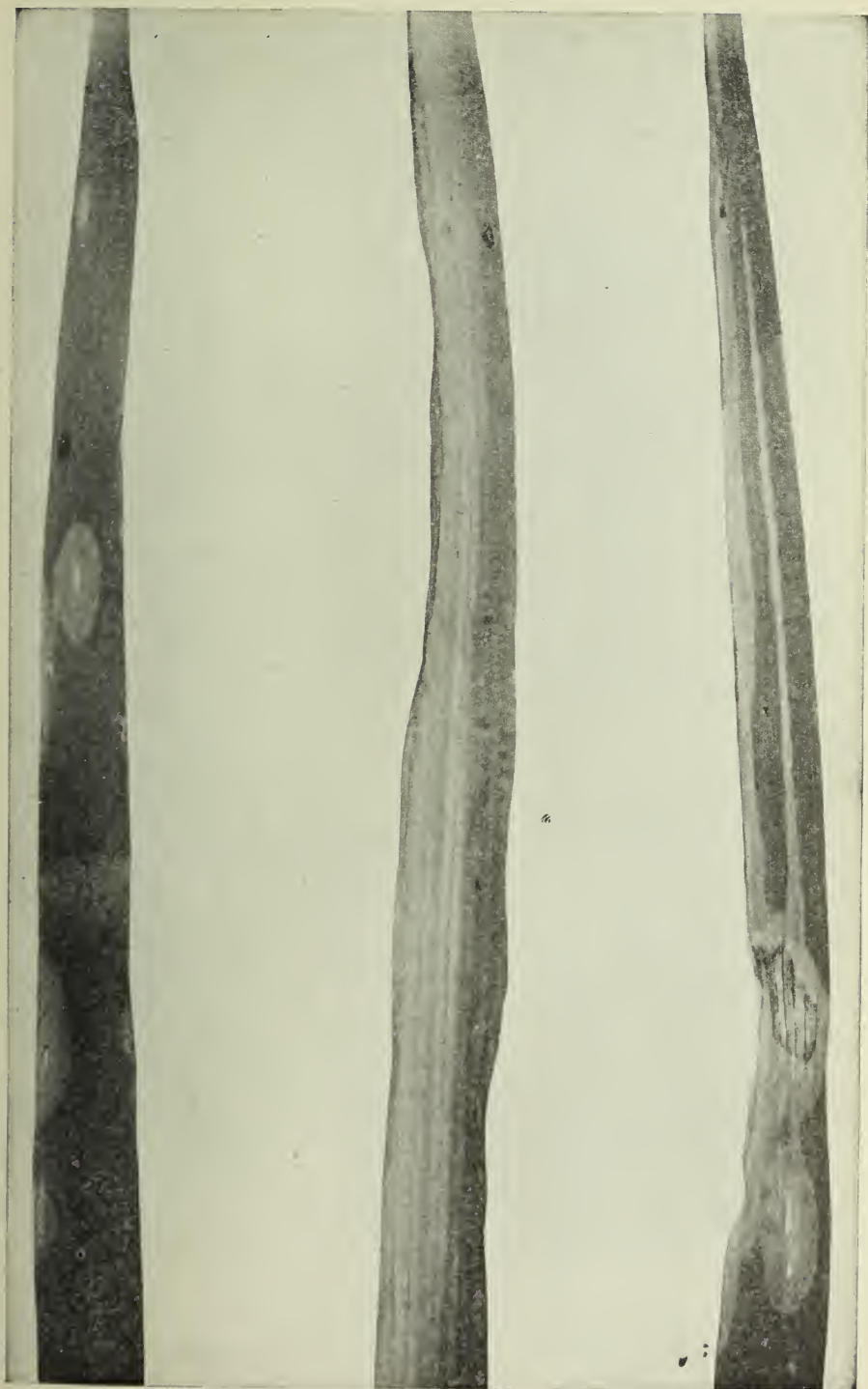
2. Showing a general yellowing of the blade due to primary stomatic infection on the stem.

3. Showing partial breakdown of a leaf due to the blight lesions becoming confluent.

NOTE: Illustrations in this plate show separate and distinct lesions. When infection is generally distributed the lesions quickly become confluent, giving the blades a mottled yellowish brown appearance.

(All from the oat variety plots, Ohio Agricultural Experiment Station, Wooster, June 15, 1909).

6-15-09. Original. Enlarged one and one-third times.



1

2

3

DESCRIPTION OF PLATE XIV.

Showing the "blast" of oats resulting from the bacterial blight disease (natural infection). In this case the flag leaf had completely collapsed, and the lesion had passed downward attacking and blasting the head. In many cases the panicle was completely killed before it had emerged from the sheath. The small light spots on the lower leaf in the illustration, are beginning lesions of the bacterial blight. This shows the disease resulting from stomatic infection by spattering of rain. The oat plants at this stage were about three feet high; many showed partial collapse due to infection of the lower leaves and culms; by two-thirds.



PLATE XIV.

DESCRIPTION OF PLATE XV.

Showing in Fig. 1 the aphid eggs found so common on apple twigs in 1908 and 1909. The writer gathered a number of these twigs (see p. 117) from different sources, and bred out the insects, in an attempt to secure *Macrosiphum granaria* or *Siphocoryne avenae* to learn whether these carried the bacteria of oat blight, to and from the apple. Upon being hatched these aphides failed to live upon the oats at all, even after several generations had been produced upon the apple, indicating that the eggs so plentiful on apple twigs in 1908 and 1909, were undoubtedly those of *Aphis mali*, the apple aphid.

Showing in Fig. 2, the first generation of aphides on the buds several days after hatching from the eggs.

Showing in Fig. 3, later generations of the aphides at work on the apple leaves. The above illustrations are from work carried out in the pathologium. All enlarged two diameters. 3-3-09 and 4-09.



SUMMARY.

1. There is prevailing throughout the oat area of the central and eastern states an abnormal condition of the oat crop.

2. Many reasons have been assigned by different writers as the cause of this condition, among which have been mentioned, physiological, resulting from the cold, wet, cloudy seasons; again, insects have been held responsible; in several instances a specific bacterial disease has been assigned as the cause. The difficulty of distinguishing the bacterial blight from other similarly appearing, but more limited troubles, has given rise to much difference of opinion as to the cause.

3. The writer finds that a specific bacterial disease is the chief factor in bringing about this abnormal condition of the oat crop.

4. This disease results from a symbiotic relation of two bacteria. Their activity is greatly favored by rainy, humid and cloudy weather.

5. The disease in its severity is chiefly confined to oats, although a somewhat similar disease has been observed to a less extent on timothy and bluegrass, and, on each of a susceptible variety of wheat and barley recently brought to the Experiment Station, for trial. In the observations on timothy and bluegrass it is to be noted that the foliage suffers but little, while the culm is killed above the upper joint.

6. The chief method of infection is through the stomata, the organisms being spattered on the leaves from the soil by rains. A secondary means of dissemination is the work of grain insects.

7. In Ohio the seasons of 1907, 1908 and 1909 have been quite favorable to the development and spread of this disease. Probably the greatest outbreak of this disease occurred in 1890, when it was observed from the Atlantic Coast to as far west as Indiana, and from the Great Lakes to the Gulf States.

8. The yields of oats in Ohio in 1890, 1907 and 1908, the three years when this blight was excessive, were reduced respectively, 36.7 percent, 24.3 percent and 14.4 percent below the average for the past eighteen years.

9. The preliminary effects of this disease is a yellowing, beginning either as small, round lesions on the blade, or as long, streak lesions extending throughout the blade or even the whole length of the culm and blades. Occasionally it begins at the tips and works back into the culm; again the upper leaves often break down through a weakened condition of the plant from defoliation below.

10. The ultimate symptoms wherever the disease has made much progress, are partial or general collapse of the leaves, due either to active lesions within the blades, or to a weakened vitality of the plant; this weakness results directly from impairment of foliage, or sickness of culm and roots. In the advanced stages the affected blades take on a mottled to almost red color, which has been called "rust," "blight," and emphasized by the expression "as red as fire."

11. It seems probable that where the soil has become filled with these specific organisms, it has become partially "oatsick." Apparent "oatsick" areas have been observed by the writer and he attributes these conditions to the bacterial blight organisms.

12. Observations indicate that the "blast" of oats is more or less directly proportional in amount to the severity of the blight disease. In some instances "blast" is directly due to active lesions of the blight killing the parts of the panicle infected. As a rule, however, it appears that "blast" results from an impaired vitality, occasioned several weeks previous to the emerging of the panicle. Heads examined one to two weeks previous to the time for their appearance showed "blasted" kernels, and the amount of "blast" was apparently proportional to the amount of blight, or in other words, to the amount of impaired vitality.

13. Some variation in the amount of blight is observed in different areas on every infected field; these irregularities are little influenced by fertility or drainage.

14. The writer has studied the morphological, cultural, physical and biochemical features of these two specific bacteria, and finding they differ from previously described organisms*, they have been named *Pseudomonas avenae* n. sp. and *Bacillus avenae* n. sp.

15. The difficulty met with in diseases which are more or less soil troubles, that is, diseases which may be carried for several years in soil without the presence of their particular hosts, have best been overcome by breeding and selecting resistant strains.

16. From observations gained through artificial inoculations and from conditions as they appear in field crops, and upon the different varieties of oats, it seems to the writer, that there is a good opportunity for selecting resistant strains.

ACKNOWLEDGEMENTS.

The writer desires to express his appreciation to those who have helped in gathering material and data for this publication; to Messrs. Rankin, Behoteguy and Goheen, for their assistance in laboratory and photographic work. The writer is especially indebted to Prof. A. D. Selby for his kindly suggestions and readiness in furthering the investigations.

* The writer reviewed the systematic works of Migula and Chester. See references (23) and (24) in literature cited.

LITERATURE CITED.

- (¹) R. H. Pettit. Special Bulletin 38, Mich. State Agric. College, July, 1907.
- R. H. Pettit. Bulletin 251, Insects of 1907, Mich. State Agric. College, pp. 113-116.
- (²) Chas. E. Thorne. Press Bulletin 286, Ohio Exp't. Sta., July 15, 1907.
- (³) H. A. Gossard. Journal of Economic Zoology, June, 1908, pp. 190-191.
- (⁴) J. Dearness. Farmer's Advocate, London, Ontario, Vol. XLII, No. 775, Aug. 1, 1907.
- (⁵) A. D. Selby. Ohio Agricultural Report, (State Sec'y. of Agric.) 1907, p. 891.
- (⁶) B. T. Galloway and E. A. Southworth. Journal of Mycology, Vol. 6, pp. 72-73, 1890.
- (⁷) Roland Thaxter. 13th An. Rept. of the Conn. Agric. Expt. Sta., 1889, p. 198.
- (⁸) C. H. Peck. New York State Report, 1889.
- (⁹) C. H. Peck. New York State Report, 1890.
- (¹⁰) G. P. Clinton. Report of the Conn. Agric. Expt. Sta., Part V, pp. 316-317, 1906.
- (¹¹) ————— Insect Life, Vol. III, p. 306.
- (¹²) F. L. Washburn. Bulletin 108, Div. of Ent., Agric. Expt. Sta., Minn., April, 1908.
- (¹³) Theo. Pergande. Bul. 44, U. S. Dept. of Agric., Div. of Ent., 1904.
- (¹⁴) Freda Detmers. An. Rept. for 1891, Ohio Expt. Sta., p. XXXIV.
- (¹⁵) James Fletcher. Dept. of Ontario Agric. College and Expt. Farm, Dept. of Bot., 1907, p. 49.
- (¹⁶) W. A. Hooker. Experiment Station Record, Vol. XX, No. 8, p. 788, 1909.
- (¹⁷) W. E. Musgrave. Philippine Journal of Science, B., Med. Sci., 3, (1908) No. 2, pp. 77-88.
- (¹⁸) A. D. Selby. Ohio Naturalist, Vol. VII, No. 4, pp. 79-85, 1907.
- (¹⁹) H. H. Whetzel. Cornell University Expt. Sta., N. Y., Bul. 236, Feb. 1906.
- (²⁰) H. L. Bolley. 14th An. Rept. of the N. Dak. Agric. Expt. Sta. for 1903, pp. 55-58, Feb. 1, 1904.
- (²¹) Thos. F. Manns. Fungi of Flax-sick Soil and Flax Seed, 1902-1904. Submitted to the N. Dak. Agric. College, Dept. of Botany, Feb. 1, 1909, for publication.
- (²²) C. G. Williams. Cir. 88, Ohio Agric. Expt. Sta., Feb. 1909.
- (²³) Frederick D. Chester. A manual of Determinative Bacteriology, 1901.
- (²⁴) Migula. System der Bacterien, 1900.

To His Excellency, JUDSON HARMON, Governor of Ohio:

SIR: In obedience to the requirements of Section 409-cc, Revised Statutes of Ohio, I herewith transmit a report of investigations on the forest conditions of Ohio, made by the Ohio Agricultural Experiment Station during the year 1909.

Respectfully submitted,

D. L. SAMPSON,
Secretary of the Board of Control.



Remnants of the primeval forest showing original trees of the white oak type

Negative by Waid

BULLETIN

OF THE

Ohio Agricultural Experiment Station

NUMBER 211.

NOVEMBER, 1909

FOREST CONDITIONS IN OHIO THIRD ANNUAL REPORT

REPORT OF THE DIRECTOR

MR. JOHN COURTRIGHT, *President of the Board of Control:*

SIR: I have the honor of submitting herewith the third annual report of the Forester of this Station for the year ending November 15, 1909.

Cooperative forest work: The cooperative work in forest management at the Boys' Industrial School at Lancaster is being continued, and the department is cooperating in the management of the fine natural forest belonging to Kenyon College, Gambier; in the planting of forest trees around the sources of water supply at Oberlin; on the grounds of the State Reformatory at Mansfield, and the new State Hospital for the treatment of tuberculosis at Mt. Vernon.

Advice and directions for the improvement of woodlots have been given to a considerable number of land owners. The number who are willing to set aside their woodlots to forestry is increasing each year and there are, at present, 606 who are cooperating with the Station in tree planting, and 263 who have applied for trees. It quite frequently happens that those who have asked for trees to plant on cleared land decide, when their attention is called to the matter, that they could do better to devote their woodlots to permanent forestry work than to plant on cleared ground. This feature of the work is given special attention because the necessity for it is so apparent.

The forest survey has been very useful in making possible a study of the forest conditions of the state; in learning the attitude of land owners toward forestry; in determining the rate of growth of different species of trees and their adaptability to various soils; in creating an interest in forestry and in helping those interested to make a start in the right direction.

The survey the present season was started in Greene county, near where the work was closed the previous season. Parties desiring trees have been visited, also those wishing to improve their woodlots, and advice has been given as to the best method of procedure. Measurements have been made of trees in planted groves and the general forest conditions noted.

During the latter part of the season the work was carried on in Washington and Athens counties. Considerable attention was given in these counties to a study of the rate of growth and to the effect of deforestation on steep hillsides in permitting erosion and landslides. A very serious condition is found to exist in the form of many eroded hilltops and valleys covered with debris.

An effort has been made to determine the percent of untillable land fit only for forestry, also the comparative amount of so-called forest which is in a productive condition, or gives promise of becoming so. Complete working plans have been made of some large tracts.

More help needed. The department is greatly in need of more trained helpers. But little of the field work can be done except by those trained under conditions which exist in Ohio. The fact that an important part of the good accomplished by the survey consists in the advice given to the owners of farm woodlots is sufficient to show that the survey should be conducted by men experienced in forestry.

Increased nursery facilities are imperative. To propagate all of the species needed for woodlot improvement requires more skill and entails greater expense than to grow catalpa and locust seedlings for grove planting. Besides a great number of trees of all species need to be grown. It is not practicable, for various reasons, to purchase trees, except a few species, hence better facilities for growing them need to be provided.

Demonstration necessary. The plan of furnishing trees to farmers is satisfactory in many respects but does not meet all requirements. There is need of more examples of woodlot improvement. Such illustrative examples should be more permanent in character than can be the case under general arrangements. Such as can be located on county farms and state institutions can serve a

useful purpose, but more are needed than can be located in this way. More and better examples could be secured if it were possible to deal somewhat more liberally with individuals; but if towns, cities or counties were enabled to take hold of the matter the work could be put on a more permanent basis.

Forest parks. To this end an enabling act is needed to permit municipalities and counties to establish forest reserves or forest parks in cooperation with the state. Such parks would serve the double purpose of parks and forests. They would be quite different from the ordinary city parks, costing far less to establish and maintain. If the state were to provide the superintendence of such forest parks the work could be made somewhat experimental in nature and serve as a demonstration as well.

The contact of the Station authorities with the owners of woodlots has shown that demonstration forest plots are greatly needed. The people want to see what can be done in tree culture and in the care of woodlots. They must be convinced by actual examples, and these illustrative examples must be numerous enough so that various methods can be shown. One or two forest parks in each county would be none too many.

Many city people are interested in forestry and such examples would be of great value to them as well as to farmers. The influence for good would constantly grow. The state could, in this way, come into virtual control of considerable forest reserves.

Respectfully submitted,

CHAS. E. THORNE,
Director.

FOREST CONDITIONS IN OHIO

REPORT OF THE FORESTER

W. J. GREEN.

A complete forest survey of the state has not been made but the work has progressed far enough to warrant the following conclusions:

1. The quantity of good merchantable timber in the state is very small. Nearly all of the trees which are now being cut and marketed are defective and were formerly rejected when the best timber was taken.

2. To harvest the mature trees which remain, in order to save them before decay has gone too far, is a matter of prudence rather than of reckless waste.

3. Many of the mature trees of our forests are of inferior species and are detrimental to the smaller trees which surround them; in fact they are weed trees and ought to be cut.

4. The most valuable trees of our forests are young trees of various ages. Their value is measured by the growth which they are capable of making. Well stocked young forests are capable of yielding a good rate of interest, even on land worth fifty dollars per acre.

Forest conservation to most people means the saving of mature trees, and nothing more. Real conservation takes into account all that is of value, also that which has a potential value.

Current ideas regarding values of forest products need an entire reconstruction, as upon a proper conception of what constitutes the most essential part of a forest rests the fundamental doctrine of conservation. To save that which is worth but little and to waste that which is full of possibilities shows wrong ideas regarding values, but examples of this kind are very common. Almost every one appreciates the worth of a large oak, walnut or pine tree, but to most people a seedling of the same species is nothing but a weed. It seems hard for any one, who has not studied the rate of growth of trees, to realize that a mature tree makes but little growth and is worth saving only as long as it remains sound, while a thrifty young tree is growing into value at a rapid rate.

A mature tree is an insecure investment and yields a very low rate of interest. Several young growing trees may occupy the same space as one large one, thus dividing the risks, and adding a much greater volume by growth.

The early settlers wisely set aside a portion of each farm as a woodlot; but they had almost no regard for any except the large, mature trees.

The value of saw timber on the farm has never been questioned but the early settlers and succeeding generations have thought of it only in terms of large trees.

Seemingly almost no one has placed any present or future value on small trees. Forest conservation has meant nothing but to save the large trees.

Down to the present time there has been almost no change of sentiment in this matter. The treatment which has been given our forests bears out the truth of this assertion. A change of sentiment in the matter is imperative.

But little will be done in the care of our timber trees until we come to realize that forest conservation means the saving of trees of all ages and sizes. This is not enough. We must learn first of all that the thrifty growing trees make up the most valuable part of the majority of our forests. We need not only to learn the value of young trees but that in giving them the proper care we are creating conditions which are the most favorable for the preservation of the large trees.

It seems to have escaped the attention of the general public, including the majority of land owners, that the most serious forest destruction which is now going on in this state is confined largely to the immature trees. Browsing animals annually kill or maim millions of seedling trees. Reproduction is thus made impossible; forest conditions are destroyed; the large trees die prematurely and the few remaining young trees fail to develop properly.

Comparatively few farmers within the state set any value upon the second-growth forest trees in their woodlots. After the mature trees are gone many owners would destroy the saplings if it were not for the cost of clearing the land. There are more land owners who are desirous of planting trees on cleared land than there are who are willing to save and care for the native forest trees in their woodlots. It is true that the trees in many woodlots are not worth saving and caring for because constant pasturing has prevented reproduction. Of 2,483 woodlots examined in 29 counties of the state about 50 percent are of this class. In some counties practically all of the woodlots have been pastured so long that grass has taken possession of almost the entire surface of the ground. In the majority of such cases it is easier and better to plant trees on tillable ground than to start them in sod, but in other counties there are many woodlots where little or no pasturing has been done and

fair stands of valuable young trees are found. In but few of these woodlots are these conditions ideal, but the cost of making improvement cuttings and of interplanting is far less than to replant anew. There are considerable numbers of young, growing forests within the state which can be improved and made valuable at a nominal expense. In their present condition some of them are not worth keeping, but many are well worth reconstructing.

Such young forests could be made valuable assets within a very few years, but if nothing is done with them they will soon be beyond the stage of reconstruction. If it were not for lack of both knowledge and faith on the part of their owners the necessary measures would be taken to put them into productive condition.

If the entire income of the state, for a decade, had been used in the purchase of land and the planting of forest trees we would have no more acres covered than we now have in second-growth forests.

The cost of these forests has been merely nominal and has not been felt. Their value as they stand would run into the millions. They offer fine opportunities for the investment of capital in the way of improvement. But they are generally not appreciated; in fact most of them would be destroyed but for the labor required.

The investigations of the Experiment Station show that the improvement of the best of these woodlands is feasible and can be done with profit. A few farmers have become convinced and have begun the work of improvement but a start has hardly been made. Forest improvement, like the good roads movement, is a matter which concerns the people as a whole. Just how the farmer may be financially aided to any extent in the work does not appear, but first of all sentiment must be created and then numerous examples of successful treatment of timber tracts must be made. What to do and how to do it varies according to locality and it is the duty of all citizens to favor any means which will multiply illustrative examples of forest operations, particularly those which have to do with the protection and improvement of young growing forests. Certain citizens whose interest and zeal are undoubted can be encouraged and helped to do forestry work of a more or less permanent character. Some very excellent work can be done in this manner, and such work is now in progress on a number of farms where the owners are cooperating with the Experiment Station. The present plan does not admit of putting the work on a sufficiently permanent basis, however.

COOPERATION WITH PUBLIC INSTITUTIONS

There are four state, one county, one municipal, two educational and two charitable institutions now cooperating with the Station in forestry work. Nurseries have been established at three of these institutions. Work of this kind is enhanced in value because of its permanency. Other institutions desire to take up such work and it is the policy of the Station to carry on as much of it as means will permit, 85,891 trees have been furnished for this purpose and about 290,000 seedlings have been grown at these institutions, some of which are now in the seed beds.

The Station is authorized by law to test the value of various species of trees for ornamental planting. Wherever forestry work is done by the Station at any institution and a nursery established, trees for ornamental planting can be included.

Not only can a considerable saving to the institution be effected in this manner but the Station can, from time to time, make notes on the value of these trees for landscape work, thus extending the scope of the operations already in progress on the Station farm.

FOREST CONSERVATION CONCERNS THE CITY
AS WELL AS THE FARM.

Many dwellers in towns and cities feel great interest in forestry and would be glad to give active aid to the cause. Some are doing so by the improvement of forest lands which they own, but there are greater numbers who are not able to do this but who greatly desire to enjoy the forests and to help along any movement tending to their improvement. The preservation of the forests for natural scenery; to check winds and hold back the waters; to harbor birds and animals; to produce materials for building and manufacturing are matters which concern city people as well as those who dwell on farms.

The obligation to protect the forests rests upon all and the opportunity to enjoy them should be enjoyed by all. Cities should own forest parks in which the design should be to get away from the conventional and costly style of landscape gardening now so common in city parks.

Such parks, if made as natural as possible, would cost far less to establish and maintain than city parks and would serve many purposes. They would help to arouse an interest in forestry and to show its practicability. They would afford means of recreation and study, supplementing the courses in school. If the Station

were enabled to cooperate in the establishment and maintenance of such forest parks the arrangement would be mutually helpful, since the work would be started along forestry rather than ornamental lines and its permanency would be reasonably sure.

THE INTEREST IN FORESTRY IS INCREASING.

It does not seem advisable at present to discontinue cooperative tree planting with farmers, but the interest in this phase of forestry is such that there is less need of fostering it than was the case a few years ago. The chief work which now needs to be done on the farm, as above stated, is to encourage the care of woodlots.

It is gratifying to note that the interest in forestry within the state is constantly growing and that the number of trees planted each year is increasing.

Catalpa and locust are the species which have been planted more than any others. These are valuable for certain purposes but our best native trees ought not to be neglected, as seems likely that they will be unless more interest can be awakened in woodlot improvement. A considerable change in sentiment is apparent however. As showing, to some extent, the awakened interest in various phases of forestry, it may be stated that during the winter and spring months of 1909 the average number of letters per month sent out by the department was 223, the total for the year amounting to 1,472. More than 50 lectures were delivered and about 300 visits made to those who desired help in forestry work.



The shaded area indicates the counties wholly or partially covered in the reconnaissance survey

A—represents the number of cooperative plots

B—represents the number of woodlots examined

C—represents number of acres in woodlots examined for each county

Clermont County

A— 10
B— 7
C—148

Brown County

A— 7
B— 8
C—148

Meigs County

A— 6
B— 15
C—536

Warren County

A— 7
B— 7
C— 148

Highland County

A— 11
B— 5
C— 127

Washington County

A— 14
B— 62
C—1450

Greene County

A— 17
B— 17
C— 502

Athens County

A— 5
B— 3
C—5095

Wayne County

A— 11
B— 106
C—1790

A RECONNAISSANCE FOREST SURVEY

BY EDMUND SECREST

Continuing the policy of making a reconnaissance survey of the forest resources of the state, initiated in 1907, the Station has during the past season been conducting a research into the forest conditions of a portion of the state, with a view as heretofore to determining the existing conditions of the native forest lands, and for the purpose of studying the various artificial plantations, established by land owners in cooperation with the Station.

Special attention was given to the study of the native woodlots, and to the making of plans of operation for those interested and wishing state aid. Preliminary steps toward making working plans were taken in the case of several large tracts. By another year data of this nature will be available for publication.

TERRITORY COVERED

The initial work begun and territory wholly or partially covered by the survey includes the counties of Wayne, Greene, Highland, Warren, Clermont, Washington and Athens. Aside from this territory numerous parties living in adjacent counties were seen upon request for the purpose of woodlot examinations.

WAYNE COUNTY

Geographically, Wayne county is situated in northeastern Ohio, in the heart of one of the excellent agricultural areas of the state.

It is situated very near the dividing line between the waters of the Lake and the Ohio River and upon the northern margin of the coal regions. Two deep preglacial channels traverse the county. One of these enters Milton township from the north, divides into two branches, one of which extends southeastwardly along the valley of Chippewa creek into Baughman township, where it expands into a broad swamp, which was doubtless the site of a prehistoric lake. The other branch from this channel extends southward, passing east of Wooster and forming the valleys occupied by the two branches of Applecreek, leaving the county at Fredricksburg. The second main channel forms the valley now occupied by Killbuck creek. It enters the county near the east half of Congress township and extends on south through the county, a branch leaving it at Millbrook which passes out at the southwest corner of the county.

In places these channels expand into fertile alluvial plains; in others, they are of a swamp-like nature indicating location of prehistoric shallow lakes. There are no high hills in the county nor very abrupt topographical features. Gently rolling hills form the surface features in general, and these are greatly modified in many places by deep deposits of drift clay. Throughout the county there is a series of glacial lakes, taking for their sites the old prehistoric channels previously mentioned. These lakes are gradually being filled by silt from the hillside wash.

In a recent soil survey by the U. S. Department of Agriculture the soils of a large part of Wayne county were described and classified. The four important types which will receive mention here are the Volusia silt loam, the Miami clay loam, the Yazoo clay and the Peat. The area of the last two is restricted and confined mostly to the proximity of the glacial lakes, marshes and swamps. These classifications are closely associated with forest types. A small part of the townships of Canaan, Milton, Greene and Franklin, and practically all of Chippewa, Baughman, Sugar creek, Paint, East Union and Salt Creek are included in the carboniferous or coal zone. The other portions of the county are of Waverly formation.

The soils are the result of glacial drift, modified by the Waverly shales and sandstones. The principal streams are Killbuck creek on the west and Chippewa and Sugar creeks in the eastern part of the county.

CLASSIFICATION OF AREAS

Each distinct soil type previously mentioned is represented by a peculiarity of forest growth. Three distinct types are easily recognizable and the line of demarcation is often quite sharply defined. These types are as follows:

1. The White Oak type
2. The Beech-Maple type
3. The Swamp type

In certain sections of the county types Nos. 1 and 2 lose their distinctive characteristics and become more or less fused. This is particularly true through parts of Chippewa and Baughman townships.

The white oak type is characterized by a once luxuriant primeval forest of white oak, having for its underwood a dense growth of dogwood. Upon the removal of the large white oaks there sprang up a growth of black and scarlet oaks with a slight admixture of white and red oak and maple. The latter frequently associates with dogwood in the formation of the ground cover. There is, of course, an occasional admixture of other species, as beech, ash

black gum, pignut, mockernut and shellbark hickories, and chestnut, but they have no significance so far as affecting the character of the forest type is concerned. This particular type is associated with the Volusia silt loam and covers generally the southern and southwestern portion of the county. While the white oak forest formerly covered this area, the age of its preponderance is passed. Its elimination from the struggle is due to two causes.

First, The uncertainty of the white oak acorn to germinate, or its propensity to germinate in the fall after dropping.

Second, Rapidity of growth. The black oak generally grow one-third more rapidly than the white oak. Thus in many places the white oak is suppressed, and in many places finally crowded out by the faster growing black oak. Hence we find the original stands of white oak replaced by the black oak.



Photo by Secrest

A characteristic Wayne county woodlot in an unpastured condition showing the margin along the southwest side devoid of undergrowth and reproduction. The wind sweeps the leaves off and a growth of grass results thereby destroying favorable conditions for reproduction.

One of the characteristic arborescent features of this type is the undergrowth of dogwood. When all destructive agencies are eliminated from the woodlot it most frequently takes complete possession, even to the exclusion of all other growth.

The following tables indicate the reversion of the growth in the white oak woodlot.

AVERAGE REPRODUCTION OF AN AREA 25 FEET SQUARE

Species	Number seedlings
Red Maple.....	480
Dogwood.....	55
Black Oak.....	35
Cherry	20
Ironwood	11
White Oak.....	12
Pignut Hickory	4
Chestnut.....	4

In this case the more inferior species have almost taken possession. The following data represent the type of woodlot seeded to white ash:

REPRODUCTION OF AN AREA 25 FEET SQUARE WHERE
WHITE ASH PREPONDERATES

Species	Number seedlings
White Ash.....	176
Mockernut Hickory	5
Dogwood.....	4
Red Maple.....	3
Black Cherry.....	3
Ironwood	1
Black Oak.....	1
Red Oak.....	1

The woodlot from which these data were taken is a splendid example of the unpastured woodlot of this type when ash seed trees are present, and when the dogwood and ironwood have not had previous possession.

Occasionally the white oak does reproduce and that usually in small groups of extremely dense stands. Considerable light, and a plentiful supply of leaf mulch and moisture, seem to be the conditions required.

THE BEECH-MAPLE TYPE

The predominating trees are the beech *Fagus Americana*, and the sugar maple *Acer saccharum*; associated with these species, may be found in varying numbers, tulip poplar *white wood*, *Liriodendron tulipifera*, red maple *Acer rubrum*, black cherry *Prunus serotina*, white ash *Fraxinus Americana*, ironwood *Ostrya Virginiana*, blue or water beech *Carpinus Caroliniana*, shellbark hickory *Hicoria ovata*, mockernut hickory *Hicoria alba*, cucumber tree *Magnolia acuminata*, and occasionally chestnut *Castanea dentata*.

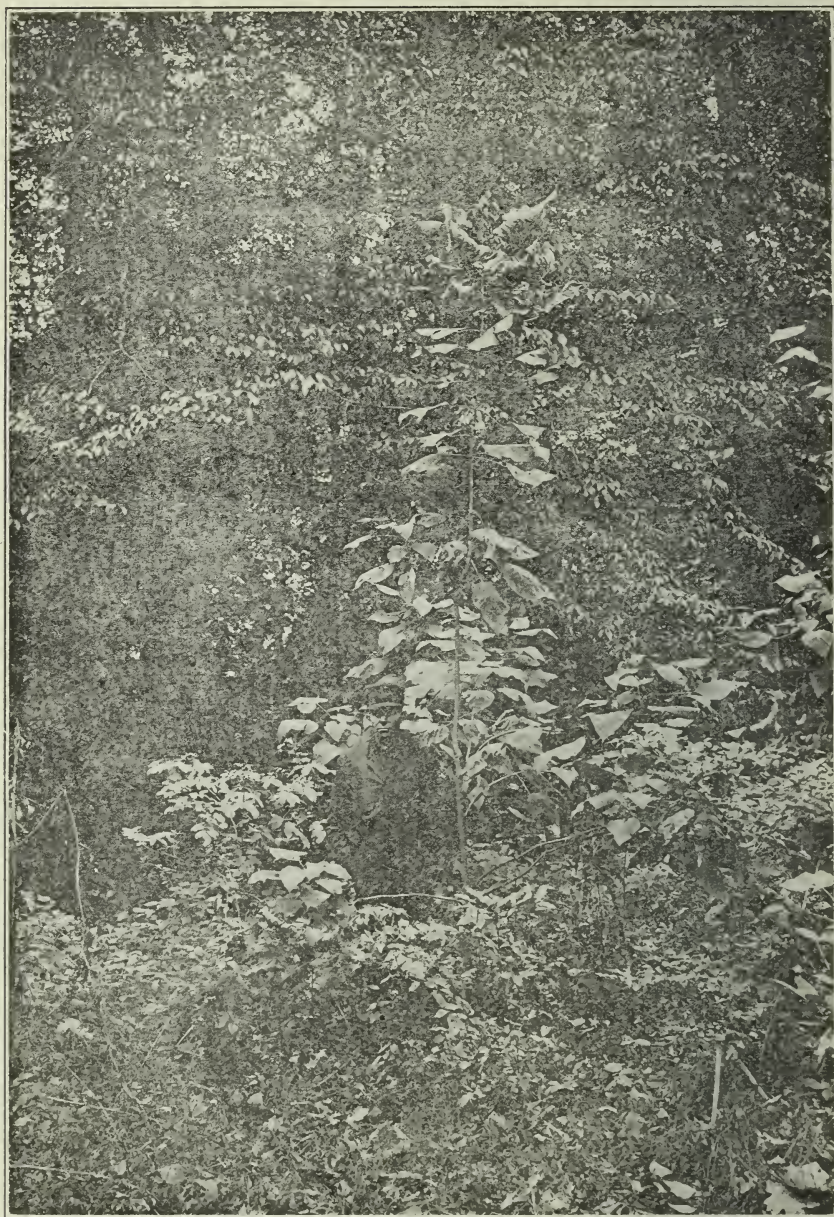


Photo by Secrest

Catalpa planted in an open space in the woods. 3 years growth

The soil of this type is a clay loam, and is classified by the U. S. Bureau of Soils as the Miami clay loam. Where conditions are favorable for regeneration sugar maple usually preponderates. Occasionally the weed ironwood takes complete possession, to the exclusion of other species. White oak also frequently reproduces quite freely and is usually found in mixtures in a greater or less degree.

REPRODUCTION IN THE BEECH-MAPLE TYPE, AREA 20 FEET SQUARE

Species	Number Seedlings
Sugar Maple	101
White Ash.....	99
Black Cherry.....	10
Black Oak.....	9

There is an absence of weed trees in the above plot, because of the absence of "seed trees" of that species. This area is a splendid type of the unpastured woodlot.

THE SWAMP TYPE

This type is confined to the glacial lakes, swamps and marshes and the larger creeks, where drainage has been restricted. The principal species found are the silver maple *Acer saccharinum*, black ash *Fraxinus nigra*, swamp white oak *Quercus platinoides*, pin oak *Quercus palustris*, burr oak *Quercus macrocarpa*, white elm *Ulmus Americana*, and occasionally the tamarack *Larix Americana*. When ash is found it usually preponderates, likewise the tamarack. The latter is found in the northeastern part of the county near Fox Lake in considerable quantity. The pin oak occurs in dense pure stands in many parts of the Killbuck Valley.

WOODLOT CONDITIONS

Five hundred and forty-nine woodlots in this county were examined in the course of the survey, and detailed reports were made upon one hundred and twelve. Eighteen percent of these woodlots were in fairly good condition as a result of not being pastured by livestock and having sufficient young growth for regeneration. Forty-nine percent were pastured, but either contain sufficient young growth to restock the area or are in such condition that they can be reconstructed. The remaining thirty-three percent constitute the woodland pasture containing an under-normal stand of either matured trees or culls and having no young growth. The ground is covered with a heavy sod and reconstruction by natural means is impractical and many times impossible.

According to the official statistics there are 298,406 acres of land in Wayne county, 35,114 acres of which are in woodland.

No large bodies of forest exist, but the woodland is cut up into areas of approximately 16 acres each. There are comparatively few purely second-growth woodlots in the county. The most common type found is the woodland pasture. Again there occurs quite frequently the remnants of the virgin forest in an unpastured state. The "remnants" in this case may be trees matured but still in good state of preservation, or they may be culls which were left for want of utilization. The young second growth has sprung up wherever spaces are created.



Large maple overtopping saplings of shellbark hickory *Negative by Waid*

THE WOODLAND PASTURE

Wayne County contains more profitable farm woodlots than any other strictly agricultural county in the state. There still remain many thousand feet of oak, chestnut, beech and maple fit for the saw. It must be said, however, on the whole, that poor forest conditions exist. Regeneration does not occur as it should, due to numerous reasons. As elsewhere in Ohio, the potent factor influencing the regeneration of the woodlot is the pasturing of the forest by live stock. Practically 80 percent of the standing woodlots are thus abused. It is true that this pernicious habit has apparently no direct influence on the forest growth—it does not affect the matured or nearly matured trees, but in the management of a woodlot for

future growth the strict exclusion of live stock must be enforced for all time to come. Were the losses incident to this practice generally known it would be largely discontinued. A woodlot is pastured not because of the nourishment derived but for the sake of the shade, and because the resulting evils are not recognized. The fact that the effects of grazing are insidious is one of the gravest dangers confronting the perpetuation of the woodlot. With the passing of the existing growth the woodlot ceases to exist, because there are no young trees, or they are of such species and quality that they possess no value.

The average value of the woods pasture, as given by owners, does not exceed 21 3-5 cents per acre per annum, while that of a properly stocked unpastured woodlot under favorable conditions and without any system of management will pay at least two dollars per acre per annum and usually more in the wood product it yields.

THE UNPASTURED WOODLOT

About eighteen percent of the timber area in Wayne County is in a fair silvicultural condition as a result of live stock exclusion. These areas have been under no system of management, but are merely the results of nature's endeavor to propagate her kind. Where conditions have been favorable considerable young growth of value may be found. In others nothing but worthless underbrush remains to succeed the present growth.

The two types of forest figure prominently in the regeneration of woodlots. Generally speaking, the beech-maple type reproduces more freely and under more adverse conditions than the white oak type, unless the latter contains ash. When this is the case that species is inclined to reproduce freely, assuming of course that the trees are good seed bearers. Throughout the southern part of the county this condition is unfortunately not frequently met with. The great majority are reproducing to the common flowering dogwood, which in many cases has taken entire possession of a woodlot, excluding any other valuable species which might otherwise take possession. No doubt the dogwood, when the stand is not too dense, often aids the ash and other species in establishing themselves but such does not seem to be the case in this county, where the dogwood grows in remarkably dense stands.

The beech-maple type on the other hand reproduces to ironwood, maple, ash, and occasionally tulip poplar. While the type is characterized by large specimens of beech there is usually little reproduction of that species. Its production of seed is uncertain. Sugar maple and ironwood constitute the prevailing reproduction.

IMPROVEMENT OF WHITE OAK WOODLOT

The woodlot owned by Mr. S. S. Taggart, lying four miles south of Wooster, is a representative type of the oak woodlot, containing white ash reproduction. It is obvious that this species will figure more prominently in the regeneration of woodlots than any other native tree.

The growth may be described as mixed, both as regards species and size. There are a few large trees of the virgin stand remaining, with considerable large second-growth individuals of black and scarlet oaks, shellbark and pignut hickory, black cherry and chestnut. The oaks preponderate. There are also a few matured individuals of black gum, ironwood, blue beech and dogwood.

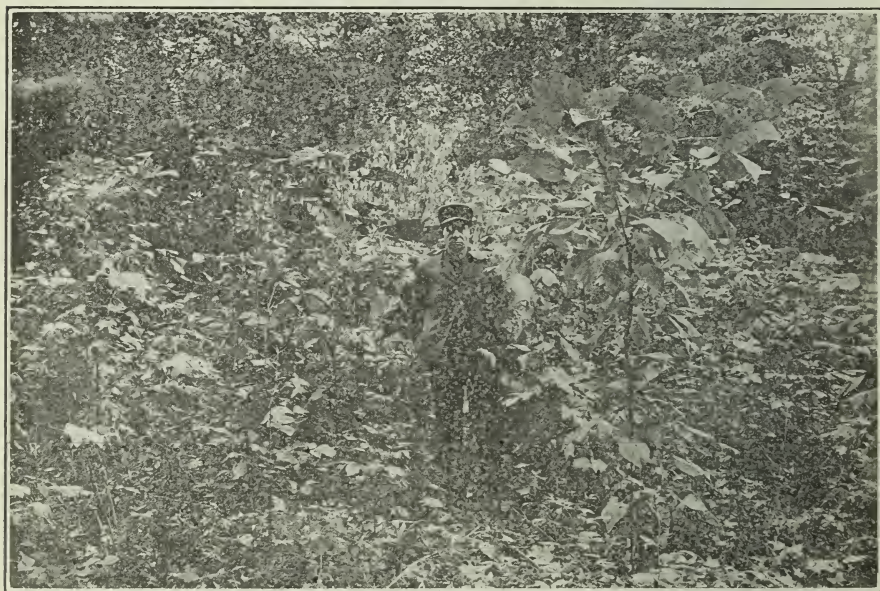


Photo by Secrest

Tulip poplar and catalpa growing in a woods, after live stock was excluded. The catalpa were planted

In parts of this woodlot there is an excellent stand of second-growth white ash, ranging in height from four to twelve feet. This growth is overtopped by large white and black oaks. These latter trees are high headed and for the most part do not seriously shade or suppress the young ash.

Along the west side of this woodlot is a strip of land running inland about one hundred feet which is entirely devoid of any young growth. In fact nothing but large, limby and matured trees form

the stand, the growing value of which is practically nil. The ground cover consists of grass, which has encroached upon the area as a result of the constant sweeping of winds, and the consequent removal of the litter. Thus conditions for natural regeneration are destroyed and the encroachment is constantly extending inward.

Another portion of this woodlot contains a dense stand of older and larger trees and less young growth. The ironwood exists in considerable quantity, being seeded from a very few matured seed trees. A number of white ash seedlings are interspersed among the ironwood, but the latter preponderates. With the exception of the strip along the west side of the woodlot the leaf mulch is well preserved and hence conditions for germination of seed are good.

PLANS FOR IMPROVEMENT

Before attempting operations in a woodlot of this kind one should have in mind a definite plan or ideal condition. A fundamental consideration would be the needs which the timber must supply. The initial operations on the above described woodlot would be the removal of the weed trees. This class includes the ironwood, the black gum and in some cases the dogwood. The ironwood is a prolific seeder and in this woodlot as well as many others of its type has taken entire possession of areas which might otherwise have been occupied by the ash. In some cases a certain amount of ironwood seeding is beneficial to a woodlot, as it is an excellent species to preserve a ground cover and leaf mulch, but where too dense it is detrimental. The safest plan is to remove the seed trees as soon as possible. The next operation would be the removal of the matured trees—those which are marketable. This operation will remove the large white oaks which are standing in the open strip which is on the west boundary of the lot. Those trees which are suppressing the young ash unless of special value should also go. The space created in the interior of the woodlot by the removal of the large trees will doubtless be seeded naturally to ash, which would be an economical means of securing a stand of this valuable species. Or if post timbers are desired the locust, catalpa or osage orange could be interplanted in these places. The strip along the west side of the lot approximately one hundred feet wide could be planted in a number of ways. The outer row of trees, however, should be evergreens. White pine or Norway spruce would be best suited for this purpose. Considerable advantage could be secured by planting the first row or two on the west side to Norway spruce and four or five rows on the inner side to white pine. The trees may be put in eight or ten foot rows and the same distance apart in the rows. The spruce is

more rigid and better able to withstand the force of the wind than the white pine, hence it is an excellent tree for the outer row. The rate of growth of the two species is approximately the same. The areas inside the evergreen belt may be planted either to locust, catalpa or osage orange. In this case the locust is better suited to the soil conditions. It could be planted in rows ten feet apart, with the trees five feet apart in the row. The sod where the pine and locust are to be planted should be broken if possible. A bull tongue plow would be a good implement for this purpose.

IMPROVEMENT OF THE BEECH-MAPLE WOODLOT

A good representation of this type is the woodlot owned by Mr. J. E. Snyder, located one and one-half miles south of Burbank, in Canaan Township.

CHARACTER OF GROWTH

The growth is mixed, both as regards size and species, with sugar maple preponderating. Aside from this white ash, red and white oak, beech, mockernut hickory, ironwood, white elm and black cherry form the species. There is considerable reproduction of sugar maple, white ash and ironwood.

The second growth and matured trees combined form a fairly normal stand. There are a number of small openings fairly well stocked with reproduction of ash, maple, elm and ironwood.

Another portion of this woodlot is practically of the same composition, having possibly more matured beech, but has been grazed for many years. No reproduction or second-growth of any description exists, and the ground cover is grass.

On the west of the woodlot is a ravine running the entire length. The ground is quite densely shaded by large beech and maple and is entirely bare of any grass or ground cover.

PLANS FOR IMPROVEMENT

This woodlot is primarily desired for the revenue it yields in the production of maple syrup. It is also very favorably situated for windbreak utility, and aside from these important features the owner desires wood products and wishes to maintain it for these reasons.

The first and fundamental principle for improvement is the exclusion of live stock; without this nothing can be accomplished. The removal of the ironwood and beech should be the next consideration. The former has seeded considerable area to no advantage, and there yet remain spots which are in need of reproduction. A thinning of large beech and maple along the slopes of the ravine should be made, so that sufficient light may enter to encourage reproduction of the

maple, which would immediately take place here. The removal of the beech from the entire woodlot should be accomplished in time, although a clear cutting of that species should not be attempted. It would be better to remove them slowly in order that they may protect the tall and shallow rooted maples from the force of high winds which have been such a potent factor in the destruction of maple groves during recent years. In order to promote the longevity of the large sugar maple the ground should be protected by a mulch, the preservation of which is due to a growth of under brush. Therefore this growth should be encouraged as much as possible and it is desirable that it be a growth of some value which will ultimately replace the older trees.

A vacant space or two exists where the soil is fertile and catalpa might be planted at a distance of six or eight feet apart each way.

Locust can be planted on each side of the ravine, after a part of the beeches are removed. The locust can be planted six feet apart each way, and plowing or cultivation in this case would not be practical.

The pastured portion of the woodlot is not worth reconstructing, owing to the absence of young growth and the almost hopeless condition of the ground cover. Natural regeneration of desired species would not occur and the existing growth is matured and of inferior species.

GREENE COUNTY

LOCATION AND TOPOGRAPHY

Greene County is located in the heart of the great agricultural belt of Ohio. There is practically no waste land resulting from topographical conditions. The eastern portion of the county is level, verging into rolling in the north portion. A part of the north townships is traversed by the deep and comparatively narrow gorge of the Little Miami, which forms an excellent example of geological erosion. This gorge is not over a few miles in extent, but is a striking topographical feature of that section. It is cut through ledges of the Niagara group of limestone, and finally broadens out into a narrow river valley.

The Little Miami River, which traverses the northern and western portions of the county, and its tributaries, Massie's creek and Caesar's creek, are the chief sources of drainage. The comparatively broad valley of the Miami in the western part of the county was doubtless opened out by glacial erosion.

SOIL

The whole county is overlaid with deposits of the glacial drift. A considerable portion of the eastern area is covered with yellow clay, passing into white and black clay according to location.

The lowlands and river bottoms, which consist of the flood plains of the present rivers, are composed of gravel overlaid with clay, loams or very frequently a loess like deposit of which land and fresh water shells make a notable element. This type is characterized by sugar maple *Acer saccharum* and black walnut *Juglans nigra*) which grow to immense size. For fertility these bottoms are unsurpassed.



White Pine planted in an open woodlot, Greene County

Photo by Secrest

WOODLOT EXAMINATIONS

During the course of the survey of this county 315 woodlots were examined and detailed reports made upon 40. Of the total number examined eight percent were unpastured and in fairly good condition. They contained sufficient young trees of value to succeed the mature growth and to form a normal stand. Twenty-eight percent were grazed to some extent; but by the strict exclusion of live stock could be saved and reconstructed. Sixty-four percent of

the total number examined were mere woodland pastures containing no young growth. The growing value of the trees is practically nothing. The ground cover is a heavy sod and the conditions for their reproduction are hopeless. Such areas will soon cease to exist.

The forest tracts of Greene County consist of irregular, detached bodies of woodland, the majority of which are remnants of the virgin forest, and woodland pastures. The former are few and the latter comparatively many. It would not seem strange that forest tracts of any size do not exist in Greene County, where the land is of the best for agriculture and is valued at \$100.00 per acre and upward. This must be expected, and will of necessity exist. Yet there are thousands of acres of so-called timberland which is by no means forest land. These areas classed as woodland pasture do not yield in the way of pasturage anything near what they are capable of doing and the amount of wood production is practically nil. If the pasture is the utility desired, it is a utility very much abused, for almost in all cases the trees are formidable barriers affecting the grass growth and its nutritive value. On the other hand, under the system of intensive pasturing the woodlot has no growing value; those trees which now stand are fast declining, owing to the absence of the protective undergrowth and reproduction. As a barrier to wind they are becoming more useless each year, and after each storm many woodlots tell the sad tale of their neglect and decline in the many fallen trees.

Forestry in Greene County, acre for acre, cannot compete with agriculture, but the products it yields for farm use and its almost priceless value as a windbreak, warrant the setting aside of a certain area on every farm for woodlot purposes.

WOODLOT CONDITIONS

TYPES

There are only two types of forest distinguishable and they are not absolute.

The Oak Type, in which the white oak, black, scarlet and red oak occur in mixtures in a greater or less degree with white ash, mockernut and shellbark hickories, red and white elm, red maple, sassafras, black cherry, dogwood, ironwood and mulberry; the young growth is usually ash, maple, ironwood, sassafras and blue beech.

The River Type, being most prominent in the valley and flood plains of the Little Miami River. The large sugar maple and black walnut and white elm are characteristic species, which originally occupied these areas. Occasionally the cottonwood occurs.

The eastern portion of the county contains little besides the woodland pasture. These areas consist of large matured trees, in many cases culls rejected by lumbermen and left standing for want of use. These trees have dead tops which present a stag headed appearance and give evidence of their rapid decline. The ground cover is grass; a condition which, combined with severe grazing, makes regeneration impossible. In many pastured woodlands there are sufficient ash seed trees to restock the area, where conditions for germination and growth are favorable.



A pastured woodlot in Washington county

Negative by Stonier

THE UNPASTURED WOODLOT

While these areas are few, they give evidence of what might be expected under somewhat favorable conditions. Where white ash seed trees are present in a woodlot of this type, that species is one of the first to regenerate, and it is largely upon this feature that the natural future regeneration of these woodlots must depend.

THE BAKER WOODLOT

This woodlot, consisting of about fifteen acres, situated about three miles south of Cedarville, in Ross Township, is probably the best representative of this type found. It was at one time severely culled, but live stock had been excluded for many years, and it is now in good condition. The species found are the white ash, shellbark hickory, white, red, shingle, burr, black and swamp oak, white and red elm, red and sugar maple, sassafras, basswood, black walnut, ironwood, blue beech, dogwood, and black cherry. The matured or culled trees comprise mostly the oak, ash and hickory.

With the exception of about five percent the area is normally stocked with reproduction and second growth. The composition of the stand is shown in the following table:

COMPOSITION OF STAND ON ONE-FOURTH ACRE PLOT

Species	Number seedlings
White ash	154
Shellbark hickory	35
Swamp white oak	14
Red maple	7
Honey locust.....	4
Shingle oak	3
Basswood	2
Sassafras	2
White elm	1
Red oak	1

The trees ranged in size from one to six inches in diameter. It will be noticed that there is a conspicuous absence of weed trees which is so frequently found in a woodlot of this type.

PLANS FOR IMPROVEMENT

The first thing to consider here is the removal of the large cull trees; although in this particular case they are high headed and do not seem to be doing serious damage to young growth. Yet they are mature and should be marketed. Their removal will create very small spaces. The removal of all ironwood, blue beech and sassafras seed trees should be accomplished as soon as possible thereafter, to prevent any seeding of the open spaces by these species. A few inferior mature ash trees should be left standing to reseed when necessary.

The utmost care should be taken in logging the area. The growth is so dense that careless felling of trees and skidding and transporting of logs would do material damage to the young growth and perhaps ruin considerable of it. Lumbering operations would

best be carried on in the fall or winter and not in the spring when the twigs of the young trees are succulent and easily damaged. Aside from the operations mentioned, and the strict reserve from grazing purposes, very little can be done to better the conditions.

THE WHITELAW REID WOODLOT

LOCATION AND AREA

This woodlot is located in Cedarville Township, about two miles north of the village of Cedarville. It consists of about thirty-five acres.

DESCRIPTION OF GROWTH

The woodlot consists of a mixed growth. There are on an average about twelve large matured trees per acre. Scattered among these trees is second growth of many sizes ranging from seedlings a foot high to trees eight or ten inches in diameter and sixty feet high. The area is not normally stocked. The young growth is grouped to a large extent and there are many spaces which could be in trees. Approximately twenty-five years ago the owner excluded live stock and planted a number of white pine, Scotch pine and sugar maple in open places among the now mature trees. On one side of the woodlot there are four groves, respectively of black locust, catalpa, black cherry and Scotch pine. While the soil is not evidently adapted to the growth of the white pine, it has thrived fairly well under the adverse conditions. On the slopes of a ravine which traverses the woodlot they have attained their best growth. While the trees have splendid form they have in but few cases been planted densely enough, nor have they had enough other trees about them to aid in proper pruning. Some of the pines are dead, apparently from blight, the cause of which is not known. The sugar maples are apparently well adapted although not native to the woodlot. They have outgrown the white pine.

AVERAGE GROWTH OF WHITE PINE AND SUGAR MAPLE UNDER SIMILAR CONDITIONS IN REID WOODS

	White Pine	Sugar Maple
Diameter $4\frac{1}{2}$ feet from ground.....	5.1 inches	5.6 inches
Height	28 feet	38 feet

The black cherry, probably the only planted grove in the state, has not done as well as might be expected. Its growth has been slow, and the trees as they stand are not thrifty. The catalpas are a mixture of the two species, there being both the bignonioides and the speciosa. Close planting with lack of thinning has somewhat

injured their development. The Scotch pine are the most thrifty of the planted groves. They lack, however, the erectness of form so characteristic of the white pine, but are without doubt more hardy and better adapted to the conditions of the soil.

SUGGESTIONS FOR FURTHER IMPROVEMENT

On the whole the planting thus far has been encouraging. Some changes in the selection of species would be advisable. It would probably be better to substitute the Austrian pine for the White, as the former species tolerates the heavier soil and the limestone formation better than the latter. The Scotch pine appears to thrive, but its habit of growth lowers the quality of its lumber. The sugar maple has thrived as well as could be expected for that species. The reproduction and second growth as it now stands is considerably grouped. The spaces should be planted.



Negative by Sponsler
A three year old locust grove, Washington county

There are but few weed trees to be found, but a considerable number of matured trees should be removed. They are in a number of instances injuring the young growth, besides constantly deteriorating in value. It is of considerable importance that they be removed before planting is done and while there are yet vacant spaces for operations of felling and skidding.

THE CATALPA

Greene County ranks among the first in the number of catalpa groves established. This species has become popular on account of its adaptability for farm purposes and its comparatively rapid growth. Many of the groves have been established for windbreaks, the needs of which are becoming generally manifest.

Considerable difficulty is yet experienced in securing the *Catalpa speciosa* true to name. Much spurious seed and many seedling trees are sold under the name of *speciosa*, which after several years growth prove to be either the common catalpa (*bignonioides*) or a hybrid of the same. A study of this species was made this summer and a detailed report will be issued by the Station during the current year.

THE OSAGE ORANGE

Several groves of this species were found in the county. The largest and oldest is probably that in the possession of Mr. O. E. Bradfute, of Cedarville Township. The trees are of ten years' growth and were planted at a distance of 2x4 feet. The soil upon which they are growing is a fertile clay loam; while the distance of planting is probably too close, they have, nevertheless, made excellent height growth and are free from limbs. It would have been better had thinning been done three or four years earlier, utilizing the thinnings for poles and stays. The matter of thinning at the present time is of course a problem. Too copious thinning would be detrimental.

In this case, where the rows are four feet apart and the trees two feet apart in the row, it would be better to remove every other row and every other tree in the rows left standing. This will open the crown cover to some extent, but it will be but a few years before it will close again. Over pruning would allow too much light to enter, inducing the growth of a grassy ground cover. In a few more years another thinning can be made, the degree of which would be determined by a number of conditions.

This indicates the possibilities in the growing of this species, and on account of the value as a post timber it would be profitable to plant on many farms in this county.

WASHINGTON COUNTY

LOCATION AND TOPOGRAPHY

Washington County lies in the southeastern part of Ohio, and borders on the Ohio river. It lies wholly within the great coal measures, and altogether outside of the drift area. The topography of the county is greatly diversified. The Ohio river flows from 300

to 400 feet below the tops of the hills which border it and from 500 to 600 feet below the highlands of the interior of the county. The principal streams of the county are the Muskingum, Little Muskingum and Hocking rivers and Duck creek, which have their sources on the highlands to the north. The branches of these streams form a network of narrow valleys which render all of the surface rolling and in some instances when the declivities are abrupt, it may be called broken.

SOILS

The soils are of four main types: 1. Alluvial, 2. Red clay, 3. Sandy clay loam, 4. Gray shaly clay.

The alluvial soils are along the larger streams and cover the flood plains and the valleys.

The Red clays are residual, resulting from the decay of the red, green and blue shales, the latter changing to red through a process of oxidation. This type is of wide extent and is rich in fertility, although heavy and impervious and difficult to till excepting under the most favorable conditions. It is subject to rapid erosion and on it are found many gullied surfaces.

The Sandy clay loam is the typical sandstone soil. As a rule it is of only moderate depth. It is porous and easily tilled, but usually lacks fertility. It is generally characterized by a growth of white and chestnut oak and pignut hickory. It occurs most frequently on the hill tops.

The Gray shaly loam is a decomposition product of green and gray shales. It is usually deep and fertile. It erodes easily, but not as badly as the red clay. This soil is often covered over on the slopes by the red clay, owing to the greater mobility of the latter.

FOREST TYPES

The forest types of this county have not the definite characteristic features, nor the sharp lines of demarcation which are found in mountainous countries. There are, however, distinctive features which may be classified into types. The following classifications will be used:

Creek Bank Type
Upland Type

Lower Slope Type
Pine Type

Old Field Type

CREEK BANK TYPE

This growth follows the creeks and rivers, from the water to the first bench. It is characterized by an abundance of buckeye, butternut, sycamore, red elm, tulip poplar, red oak and basswood.

It consists almost wholly of second growth. The scattered tulip poplars and red oaks are the only valuable trees. The butternut does not appear to reach merchantable size on the characteristic shallow soil of this type.

It is unfortunate that these areas have a poor composition, for the forest conditions are unusually good, and the proper selection of trees would ultimately mean a splendid forest.



Shortleaf and pitch pine, Washington county

Negative by Sponsler

PLANS FOR IMPROVEMENT

In many cases these areas contain seed trees of tulip poplar and red oak, but the reproduction has little chance to survive, owing to the presence of buckeye and butternut, and in some cases blue beech. Hence it is important to remove or at least thin out these latter species. In some instances the red oak and tulip poplar are lacking entirely and the growth is made up of buckeye, elm and butternut. In this case it would be better to make a clean cutting and plant the areas to some species well adapted. Tulip poplar, black walnut or red oak could be used for this purpose. If the two

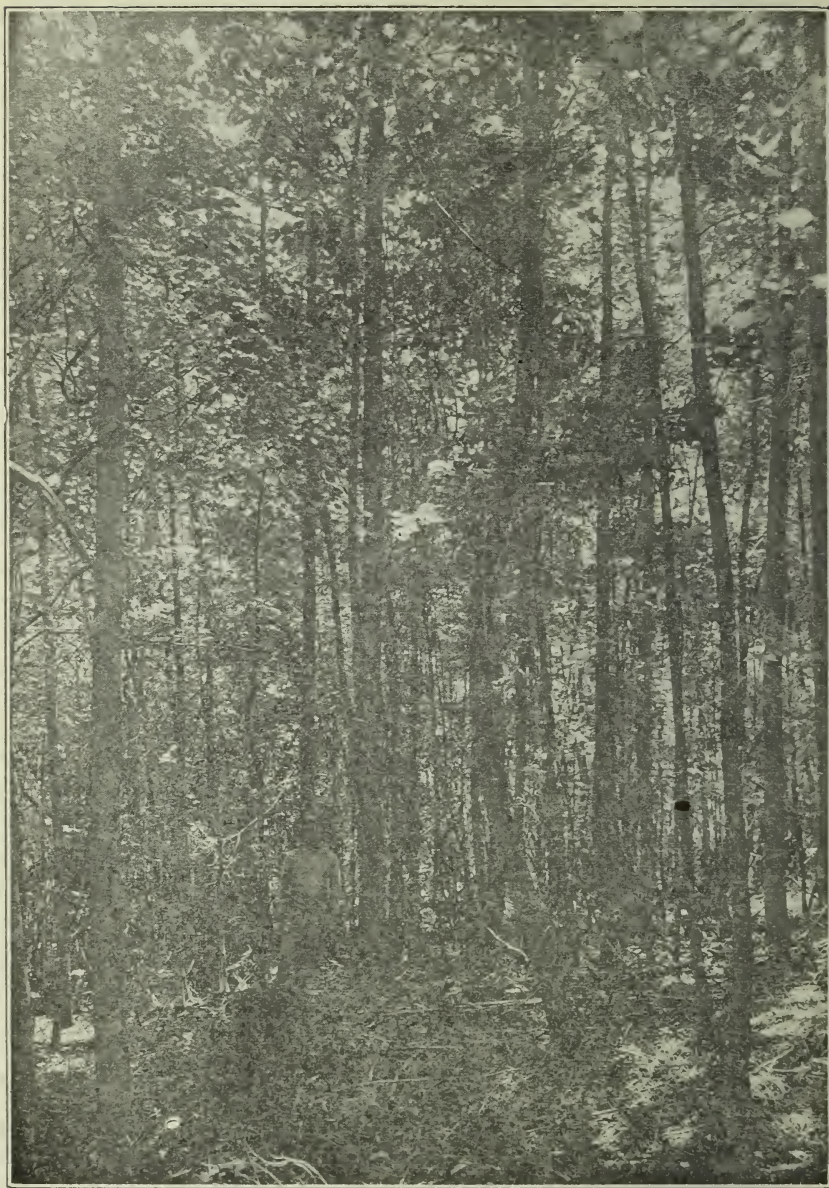
former species are used it might be a good plan to plant sugar maple in mixture with them. This would help to preserve forest conditions, which a pure planting of poplar and walnut would not supply, owing to their light foliage, and hence inability to shade the ground. The maple possesses this quality to a marked degree, on account of its heavy foliage and consequent shade tolerance. In many instances there are sufficient maple seed trees of either the sugar or red maple to reseed the area for the purpose mentioned.

LOWER SLOPE TYPE

This was originally a white oak and tulip poplar type, with red and sugar maple as an underwood. The tulip poplar has disappeared except for an occasional tree. The white oak likewise is fast disappearing, leaving the beech with scattering seed trees. The percentage of species in mixture may be said to be approximately:

Beech.....	70%
Sugar and red maple...	15%
Red oak ..	6%
Scarlet oak.....	5%
Sassafras and butternut.....	4%

In Independence township the chestnut and sourwood occur frequently in mixture. They are, however, restricted to the east side of the Muskingum river. Where the beech predominates the stand is usually broken and admits the second growth sugar and red maple, red and white oak. Where the beech has been cut clear the stand is more variable and is chiefly coppice white oak, beech, red and black oak, black gum, red and sugar maple. In places the growth of sassafras has become serious. The ironwood frequently appears, but in few places is it present in sufficient quantities to affect the condition of the forest. While the area of this type is not large, yet its future is of considerable importance, because of the possibilities in the way of growth. Practically all of the species which will figure permanently in the future forest are now or at one time have been growing on these areas. Moreover, for topographical reasons they cannot be utilized for agricultural purposes. The forest conditions in most cases are good. The sheltered position and density of canopy have retained moisture and favored humus. The absence of grass, caused by the dense crown cover, has discouraged pasturing, hence danger from this source is not likely.



Negative by Sponsler

A stand of thrifty second growth tulip poplar

PLANS FOR IMPROVEMENT

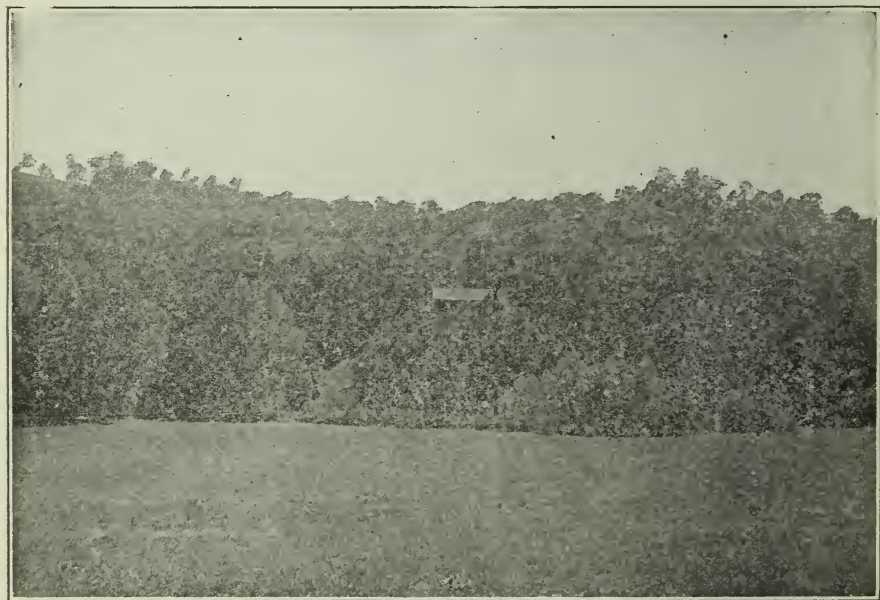
The first consideration in attempting to improve the woodlots of this type would be the encouragement of those trees found native at one time, but which are being superseded by the more prolific and undesirable species. The tulip poplar, red oak, basswood and under certain conditions the sugar maple would be the trees to save. The elimination of all weed trees then would be the first operation. The removal of the beech is the most pressing need. Likewise the black gum, ironwood and buckeye are a serious hindrance to the regeneration of the poplar and oak. The obstacle in the way of the removal of beech would be the lack of a market for the wood product. A simple method of disposing of the trees would be to girdle and leave them standing, although their removal would be better. These operations will largely aid the regeneration of the poplar, whose most pernicious enemy is the overtopping and dense shade of these weed trees. In many instances it is advisable to resort to planting, especially where sufficient seedlings and seed trees of desirable species do not exist. The tulip poplar, red oak, and in some locations chestnut, are the practical species to consider. The European larch and bald cypress might also be considered. The species mentioned should be used in mixture with some heavy foliaged, tolerant species, preferably the sugar maple or red mulberry. It is especially urgent that the larch and cypress be used with some heavy foliaged species as their leaf crowns are not capable of shading the ground sufficiently to exclude the grass and create the necessary humus and ground cover.

The proper distance of planting will depend somewhat on the species used and other conditions. On an average, 6x6 feet is a safe distance. The heavy and light foliaged trees can be alternated in rows.

THE UPLAND TYPE

This comprises the largest area of the forest lands and is characteristic of the plateau lands. Originally white oak was the predominating species. It has been somewhat superseded by the black and scarlet oak, and pignut and mockernut hickories. The primeval forest consisted of giant white oaks. Few of these specimens remain, and the second growth of white oak is gradually being eliminated in the struggle for existence. There are occasional second growth stands which are thrifty, but the composition is nearly pure. Where the black and white oak occur together the white will eventually be superseded by the black. This type chooses the dryer sites, hence the growth of the trees is usually slow, and the

results of pasturing and over exposure of the soil are very evident. This type is reproducing quite well, the second growth being mostly oaks except where severely pastured. In that case the percent of hickories is on the increase. There are occasionally scattering white ash trees in this type, but where the heavier clays abound and forest conditions are good, reproduction is quite frequently abundant. The stands examined, however, seem to lack the soil fertility and moisture necessary to mature them. Doubtless a heavier foliated species in mixture would have served to build up their site and hence increase their thriftiness. Moreover, a considerable portion of this second growth is pastured, which is doubly injurious in a dry site of this nature which demands the very best forest conditions.



Black locust taking possession of an abandoned field

Photo by Secrest

The east and north slopes are naturally in better silvicultural condition than the north and west slopes. The forest and silvicultural conditions are usually poor on the latter, especially where a culled condition of growth exists.

Probably 75 percent of the area of this type has been severely culled over. In the process an excess of black oak has been left.

Quite frequently there occur on the dry, sandy hill tops dense stands of chestnut oak, consisting almost entirely of second growth, which resulted in many cases from stump sprouts. This growth is characterized by an undergrowth of huckleberry and often laurel, the latter occurring only on the thinnest and most barren soils. Occasionally black locust may be found in mixture, usually in an unthrifty condition, however. There are but few original trees of the chestnut oak remaining. Practically all have been removed in the past for tan bark.

PLANS FOR IMPROVEMENT

Grazing is the potent factor influencing this type of woodlot. The first step should be to reserve the area from livestock. Owing to the comparatively dry situations upon which this type exists the best possible conditions must be preserved through the accumulation of leaf mold, by means of undergrowth.

The removal of all matured trees, would also be important. In some woodlots large, cull white oaks are standing, and in many instances are doing material harm to young trees. The scarlet oak may be considered a weed tree and its elimination is necessary in the selection of species to form the stand. Wherever the ash tends to reproduce all efforts should be made to favor this species. When ash seed trees are present, all worthless undergrowth should be removed, especially where the crown cover completely covers the ground. This will encourage the reproduction of the ash. An admixture of red maple would improve the quality of the site and be of benefit to the ash.

A considerable number of woodlots of this type consist of fairly normal stands of second growth black oak, varying in size from eight to fifteen inches in diameter. Very little can be done to improve the conditions of these areas except to reserve them from grazing. Occasionally the stands of trees are thin enough on the ground to permit of interplanting. The species which figure in the reconstruction of woodlots of this type are few. The locust would be a good species to interplant where the growth is too thin. On the chestnut oak soil the white pine could probably be used to advantage, as could the shortleaf pine *Pinus echinata*. Red oak could be used on the moister slopes.

PINE TYPE

On western exposures and dry hill tops there may be found occasional groups and mixtures of shortleaf, Jersey, pitch and white pines. The species frequently occur in mixture with black and

chestnut oaks and pignut hickory. These areas are not extensive nor very valuable. The pines are practically all second growth, and are apparently encroaching upon the hardwoods in the dry sites. In many places pine reproduction will be found among the thinner hardwood stands, where it is being fostered by the shade of the latter. The shortleaf, pitch and Jersey pines take possession of old fields, and in a number of instances they are found slowly encroaching upon such areas which are in close proximity to seed trees. Of the species found, the shortleaf pine is of the most economical importance as its growth is more rapid, straighter, and the lumber product is of higher value. While the product of the white pine has a higher commercial value, it does not exist in sufficient quantities to be considered except as a valuable tree to be used for future planting.



Pitch pine encroaching on an old field

Photo by Secrest

THE WHITE PINE

This species is found growing upon a limited area on the east ridge of Leith Run in Grandview Township. It seeks the south slope and is associated with white, black and chestnut oaks, and beech, white ash, sorrel wood and a small amount of Jersey and pitch pine. The white pine occupies about twenty percent of the mixture. While the trees are existing under poor conditions they

have made fairly good growth, and some of them show two and one-half feet between nodes. On the third fork of Mill creek is another stand which is considerably denser and shows better growth. Some of the stumps indicate a 12 inch tree in 40 years, under natural conditions.

Were the thinning of hardwoods accomplished the area of the pine forests could be considerably extended and the quality of wood product very much improved. In many places the trees stand too thin. They do not prune themselves and the stands are nowhere normal.

OLD FIELD TYPE

This type is commonly met with on the east side of the Muskingum river and it sometimes occurs on the west side. In Independence township about fifteen percent of the forest area comprises the growth which has come up in abandoned fields. Two species figure prominently in this type, the locust and hickory. There are many large thickets of the former, occurring on old fields and pastures where the soil is often too exhausted to produce anything else. Quite frequently it is associated with hickory and sassafras. These stands have come into existence only recently. The presence of large locust trees in close proximity to a sterile field or pasture, upon which no stock was allowed to roam, served to seed these areas, and doubtless much of the reproduction was secured by root suckers. A peculiarity exists here that is rarely met with, viz., the apparent ease with which the locust reproduces itself by seed.

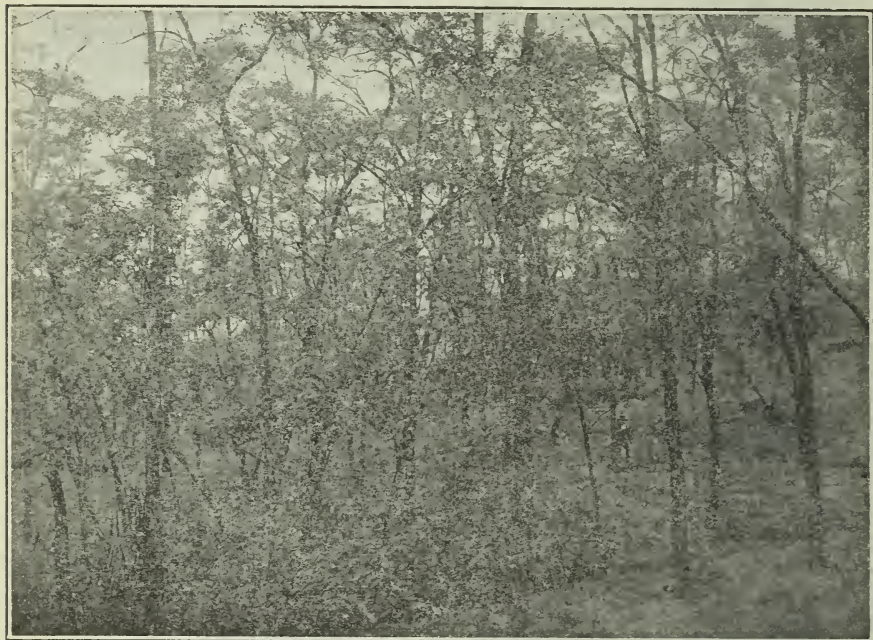
The type is of great importance to the county, and it is being recognized as such.

EXTENSION OF THE OLD FIELD TYPE

The stands of locust as they now exist often lack sufficient density, or are grouped, leaving large spaces unoccupied. The prolific suckering propensities of the locust are commonly known, and it is through this feature that the group may be extended and greater density secured in thin stands.

In breaking the roots of the species a sprout will result. Where extension is desired the ground about the roots of the trees should be broken by plowing furrows about six feet apart in the direction the grove is to be extended. This operation may be kept up each year until a sufficient number of sprouts are secured to restock the area.

In many cases it will be found necessary to remove "weed trees" from among the locust. Sassafras and hickories often times consume space and overtop the locust.



Negative by Sponsler

A splendid blue grass pasture produced from once sterile ground by the influence of the black locust. The locust grove is about 25 years old and is valued at \$120.00 per acre

EROSION

The erosion and abrasion of soil on hundreds of acres of land in this county is one of the startling features evidenced by the study of conditions. In many places the soil has been tilled until the vegetable fiber is exhausted and nothing remains but the exposed and gullied surfaces of clay. Thousands of tons of earth are annually carried into the streams and rivers, taking the best soil down to the impenetrable subsoils, and the trouble is just beginning. This erosion is not only detrimental to agricultural interests, but is of far greater consequence to the water flow, the water stages being influenced unfavorably by the accumulation of soil and silt, resulting in hindrance to navigation in the larger rivers, and the condition at the head waters of each effluent must ultimately be reflected in the flow

of the main rivers. The loss to land owners entailed through erosion is annually enormous. This erosion is not only resulting in the actual deterioration of the soil but also in the loss of paying crops. In some few instances these areas may be profitably reclaimed by the addition of fertilizers and the seeding to grass, but in the vast majority of instances where the wasting process has gullied the land, such a procedure would hardly be practical. Tree planting is the only hope, and the sooner it is recognized the better.

(A detailed report on Landslides and Erosion will be issued by this Station during the current year).



Stopping the wash by planting locusts

Photo by Sechrist

THE TULIP POPLAR

One of the most striking arboreal features of the county is the second growth tulip, or yellow poplar grove on the farm of Mr. F. F. Graham, near Vincent, in Barlow township. This grove is situated on a ridge of pure sand which is underlaid with yellow clay. In a sand pit the roots may be seen to extend ten or fifteen feet into the sand. The woodlot is in several stages of growth, the final result of which will be a pure stand of poplar. Among the poplar are growing white ash, red maple, sassafras and dogwood, all of which the poplar will supersede in time.

The tulip poplar is in various stages of development. A portion of the growth is about eleven years old, a part sixteen years old and another part twenty years old. The latter portion of the grove is in need of thinning.

Owing to the light leaf canopy of the tulip poplar it would not be wise to make a heavy thinning unless a heavy underwood remained to protect the site, and such growth is ceasing to exist in the grove. It would doubtless be the best plan to make a heavy thinning and underplant with sugar or red maple. In some places the red mulberry might be used. This would give the poplar an excellent chance to develop and at the same time the soil conditions will be preserved and improved by the heavy foliaged maple.



Waste in cutting white oak ties

Photo by Secrest

COMPOSITION OF 20-YEAR-OLD TULIP POPLAR FOREST
DATA FROM AREA 50 FEET SQUARE

Species	Diameter in inches, 4½ feet from ground								Total number
	1	2	3	4	5	6	7	8	
Tulip poplar.....	1	1	3	6	7	5	1	2	35
White ash	1	2		4	5				12
Pignut hickory ...	2	1							3
Sassafras		1	3	3					7
Red maple.....	1								1
White oak	2								2
Black cherry				1					1
Black gum		2							2

MARKET CONDITIONS

The lack of dependable markets for wood products is the discouraging feature in the practice of forestry. The demand for board stuff and construction material is greater than it was, but that material is almost exhausted. The product now available in the form of the second growth and the culled trees of the original forest which it is often necessary to remove from the woodlot and dispose of, has little or no market value. Coal has practically driven fire wood out of the market, so that usually no value can be placed upon wood for that utilization. In some cases a nominal price may be obtained for mine props. This does not exceed one cent per linear foot. The tie market in many cases is the most profitable when timber of that dimension is at hand. At the present time white and chestnut oak ties are selling at from 50 to 60 cents per tie. Red, black and scarlet oak and chestnut sell from 35 to 50 cents per tie, delivered at the railroad.



Second growth chestnut oak, Washington county *Negative by Sponsler*

WASTE LANDS

Washington county contains a total of 297,773 acres of land, 29,328 acres of which is classified as waste land, which is practically ten percent of the area. A portion of this waste is a result of topo-

graphical conditions, and a portion that of erosive processes. The latter form the largest areas, and they are on the increase. Much of the land comprising the steep slopes contains a sparse growth of timber which has neither real nor potential value, much of which has been brought into productiveness by forestry practices. Of more importance are those areas which erode, and they are so numerous and the work of destruction has progressed so far, that cure as well as prevention must be considered.

The best "cure" in most of these cases is trees, but it must first receive recognition as such. Nature herself proceeds in this manner, and the results manifest themselves in the many locust and pine thickets on eroded lands throughout the Appalachian plateau.

Time, patience, courage and resource will be required to bring these areas back to productiveness and its importance as an agricultural problem in southern Ohio is second to none.

BULLETIN

OF THE

Ohio Agricultural Experiment Station

NUMBER 212

DECEMBER, 1909

CORN JUDGING: STUDIES OF PROMINENT EAR CHARACTERS IN THEIR RELATION TO YIELD

BY C. G. WILLIAMS AND F. A. WELTON

The time has perhaps come when this Station is able to draw some conclusions from experimental data as to what ear characters are associated with high yielding corn. Work was begun in a small way five years ago in the study of the relation of length of ear to yield. Four years ago it was extended to a study of the relation of shape of ear to yield, and later to the filling of the tip, the indentation of the kernel, the weight of ear and the effect of previous environment upon the value of seed corn.

It has been thought best to make a preliminary report of this work although the questions asked are a long way from being permanently answered. However, the answers recorded may turn some light upon corn judging, or the selection of seed corn.

In the study of these various characters the aim has been to have the groups compared differ widely with reference to one character only. Little or no attention has been paid to other characters except to have all sorts represented, the thought being that one character would offset its opposite, giving a fairly accurate comparison of the groups and the character studied.

Each group has consisted of from 25 to 100 ears and has been represented by a composite sample of seed made up of a few rows of kernels taken from each ear. While it is well known that ears of corn vary in their ability to yield from perhaps invisible, though heritable characters, in the numbers in which they were used in these tests it is presumed that such variation would be cared for; that is, that high and low yielding ears would be found in each group.

The size of the plots used in this work has been one-tenth acre. The conditions of growth as affected by previous treatment of soil have been quite uniform. For the last sixteen years not a furrow has been plowed, nor a pound of fertilizer put upon one plot without similar treatment being given the other plots of the series the same day.

In planting these test plots an excessive amount of seed has been used and the plots thinned to a uniform stand when the plants were six to eight inches high.

1. THE RELATION OF LENGTH OF EAR TO YIELD

Attention is called in the first place to the relation of length of ear to yield. In Table I is reported a test conducted in 1909 with four varieties of corn. Upon two of these plots corn of the third generation of continuous selection of long and short ears was used. Upon four plots, corn of the second generation, and upon four more, corn of the first generation.

TABLE I: The relation of length of ear to yield, 1909.

Variety	Average length	Average weight	Av. circ		Yield per acre	Excess length of long ears over short Ins.
	Ins.	Ozs.	2 in. from butt	2 in. from tip	* Bus.	
Clarage (a)	8.9	10.6	6.5	5.8	84.77	
Clarage (a)	6.6	8.8	6.7	6.1	79.15	
Gain for long ears					5.62	2.3
Leaming (b)	9.3	12.1	7.2	5.9	95.18	
Leaming (b)	7.1	9.9	7.4	6.4	90.41	
Gain for long ears					4.77	2.2
Darke Co. Mammoth (b)	9.7	13.3	7.0	6.2	99.47	
Darke Co. Mammoth (b)	7.2	10.9	7.5	6.9	92.70	
Gain for long ears					6.77	2.5
Reid Yellow Dent (c)	10.6	13.8	7.0		88.47	
Reid Yellow Dent (c)	8.2	11.7	7.2		82.28	
Gain for long ears					6.19	2.4
Leaming (c)	9.4	12.8	7.3		92.74	
Leaming (c)	7.8	10.4	7.4		90.21	
Gain for long ears					2.53	1.6
Average gain for long ears—10 plots in test					5.18	2.2

(a) Third generation of long and short ears.

(b) Second generation of long and short ears.

(c) First generation of long and short ears.

* Fall weights corrected to a uniform moisture content of 15 percent.

It will be observed that in every instance the long ears lead in yield, by amounts ranging from 2.53 to 6.77 bushels per acre, with an average of 5.18 bushels. It will be noted further that the greatest increase in yield comes in the group in which there is the greatest difference in length between the long and short ears, while the least increase in yield comes in the group in which there is the least difference in length.

However, differences in length of ear are not the only differences existing in these several groups. In Table II we have these same groups arranged so as to compare their differences with reference to other characters, as follows:

TABLE II: A study of the long and short ears reported upon in Table I with reference to length, weight, shape, circumference and proportion of circumference to length.

Variety	Long or short ears	Excess in length	Excess in weight	Excess in circumference (butt)	Excess of butt circumference over tip circum.	Excess in yield	Proportion of circum. to length
		Inches	Ounces	Inches	Inches	Bushels	Percent
1 Clarage	Long	2.3	1.8		0.7	5.62	73.0
2 Clarage	Short			0.2	0.6 <i>d</i>		101.5
3 Leaming (<i>b</i>)	Long	2.2	2.2		1.3	4.77	77.4
4 Leaming (<i>b</i>)	Short			0.2	1.0 <i>d</i>		104.2
5 Darke Co. Mammoth....	Long	2.5	2.4		0.8	6.77	72.2
6 Darke Co. Mammoth....	Short			0.5	0.6 <i>d</i>		104.2
7 Reid Yellow Dent	Long	2.4	2.1			6.19	66.0
8 Reid Yellow Dent	Short			0.2			87.8
9 Leaming (<i>c</i>)	Long	1.6	2.4			2.53	77.7
10 Leaming (<i>c</i>)	Short			0.1			94.9

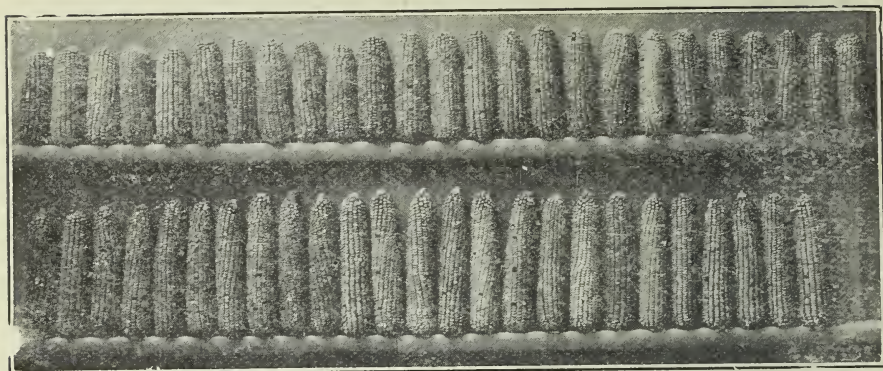
(*b*) Second generation.

(*c*) First generation.

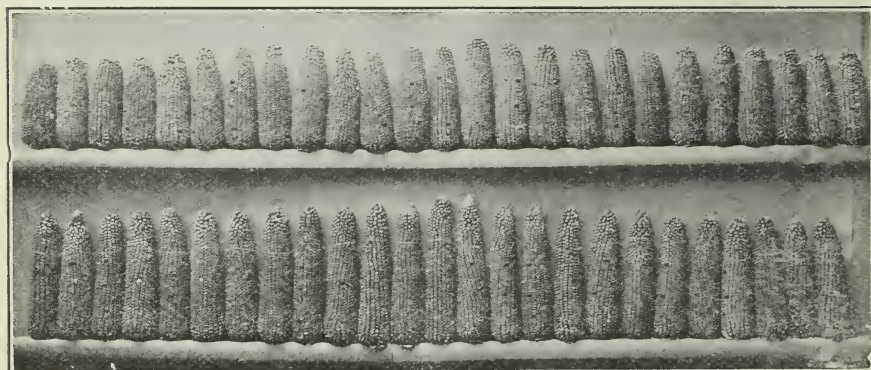
(*d*) More cylindrical.

It is to be noted, as would be expected, that these groups of long ears average higher in weight of ear also. Is it possible that this excess in weight may have had as much to do with the increase in yield as has the length? That it has something to do with it is probable. Note, however, that, while the group of long ears (5) showing greatest increase in yield and greatest length also stands at the top in weight, there is another group (9) equaling it in weight, but at the other extreme in yield. The latter group is lacking in *length* as well as in yield.

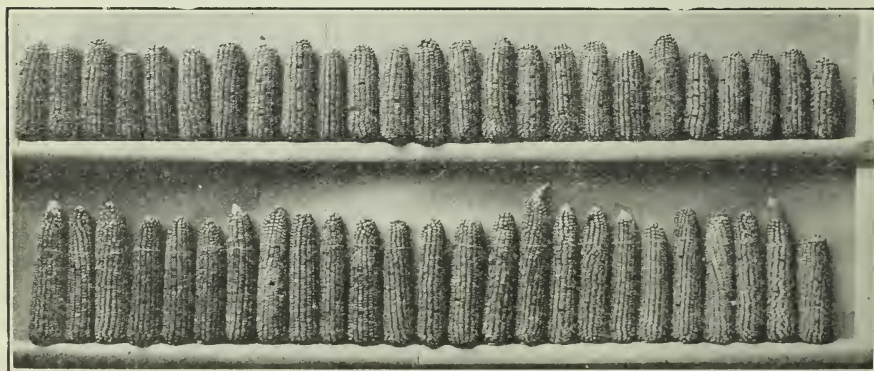
The short ears—and low yielders—invariably exceed the long ears in circumference. This would seem to indicate the impossibility of increasing the yield of short ears by increasing their circumference to make good their lack in weight, providing weight be a factor of significance in increasing yield.



Darke Co. Mammoth. Long and short ears.



Leaming. Long and short ears.



Clarage. Long and short ears.

TABLE III: The relation of length of ear to yield. Summary of 22 tests on 44 tenth-acre plots, 1905-1909.

Year	Variety	Long or short ears	Yield of shelled corn per acre * Bus.	Increase in yield Bus.
1909	Clarage	Long	84.77	5.62
	Clarage	Short	79.15	
	Leaming	Long	93.96	3.65
	Leaming	Short	90.31	
	Darke Co. Mammoth.....	Long	99.47	6.77
	Darke Co. Mammoth.....	Short	92.70	
	Reid Yellow Dent	Long	88.47	6.19
	Reid Yellow Dent	Short	82.28	
Average gain for long ears				5.18
1908	Clarage	Long	68.22	0.45
	Clarage	Short	67.77	
	Leaming	Long	73.50	4.40
	Leaming	Short	69.10	
	Darke Co. Mammoth.....	Long	78.25	5.06
	Darke Co. Mammoth.....	Short	73.19	
Average gain for long ears				3.31
1907	Clarage	Long	64.95	0.43
	Clarage	Short	65.38	
	Leaming	Long	63.41	3.15
	Leaming	Short	60.26	
	Reid Yellow Dent	Long	58.62	1.58
	Reid Yellow Dent	Short	60.20	
Average gain for long ears				0.38
1906	Clarage	Long	66.88	8.12
	Clarage	Short	58.76	
	Leaming	Long	78.40	6.02
	Leaming	Short	72.38	
Average gain for long ears				7.07
1905	Leaming	Long	97.05	4.20
	Leaming	Short	92.85	
Combined average of 22 tests, gain for long ears				3.97

* For 1909 ear corn corrected to 15 percent moisture content, 70 pounds of which will approximate shelled corn bushels.

In Table III is given a summary of the 22 tests conducted during the past five years in the study of long as compared with short ears. Many of these tests were in duplicate. Of those duplicated, the average of the two plots is given.

It will be noted that the long ears are in the lead each of the five years, although one year the lead is insignificant. The combined average of all the tests gives an advantage of 3.97 bushels in favor of the long ears.

Illustrations on page 216 give an idea of the character of the ears compared.

What has been the tendency of this continued selection of long and short ears upon the length of ear of the crop grown?

This continuous selection began with the Clarage corn in 1907. Thirty-nine short ears were selected, averaging 7.1 inches in length, and 39 long ears averaging 9.4 inches. A composite sample, made up of a few rows of kernels from each ear, was planted upon tenth-acre plots, the plot from the short ears being grown beside the plot from the long ears each year, no effort being made to prevent inter-crossing.

The length of each ear of corn grown from these selections was measured. The average length of ear from the short ears was 7.12 inches; from the long ears 7.56 inches: a difference of .44 inch. The length was measured about a month after husking and before the ears were fully shrunken, while the seed ears planted each year have been measured in the spring, shortly before planting.

For the plantings of 1908 and 1909 short and long ears were selected from the preceding crop of the same class. The crop was not measured in 1908, but was in 1909, as in 1907, when the average length of ear was 6.87 inches for the short ears and 7.92 inches for the long ears. A difference of 1.05 inches in 1909 as compared with 0.44 in 1907.

It should perhaps be stated that ears of all lengths, including nubbins, were measured both years.

TABLE IV. Variation in length of ear in seed and progeny.

Year	Seed used			Crop harvested			* Yield per acre		
	Long ears, Av. length Inches	Short ears, Av. length Inches	Difference Inches	Long ears, Av. length Inches	Short ears, Av. length Inches	Difference Inches	Long ears Bus.	Short ears Bus.	Difference Bus.
1907.....	9.43	7.11	2.32	7.56	7.12	0.44	64.95	65.38	-0.43
1909.....	8.90	6.60	2.30	7.92	6.87	1.05	84.77	79.15	+5.62
Comparing 1909 with 1907	-0.53	-0.51	-0.02	+0.36	-0.25	+0.61	+19.82	+13.77	+6.05

* Shelled corn for 1907. Ears, corrected to 15 percent moisture in 1909.

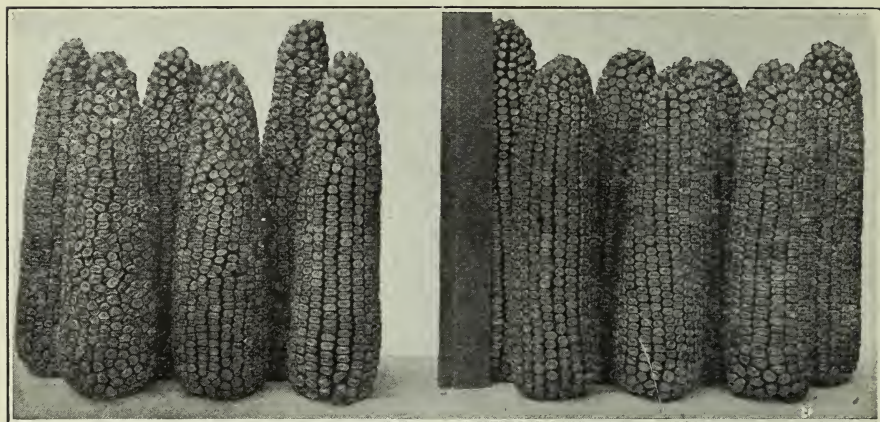
While the seed of the long ears used in 1909 is not of as great average length as that of 1907, this fact would seem to be due to a matter of environment. At any rate the inherent character seems to be present, for it is asserted in the progeny.

That the average length of ear can be quite rapidly changed is probable. The plant breeder will be interested in accounting for this change. Are we adding together the slight fluctuations discoverable year by year, or did we have in the first selection all we now have in these heritable characters, the advance made being due, not to the addition, little by little, of the character in question, but to the purification of the type by the weeding out of the opposite character—to subtraction rather than addition? The practical corn grower will be interested in the fact, though possibly not in the theory.

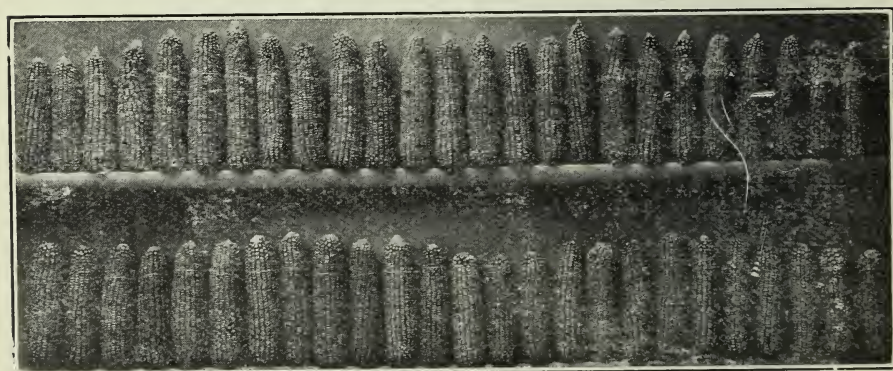
Conclusion: If a given quantity of seed corn be divided into two groups, one composed of ears below the average length and the other above, the longer ears will out-yield the shorter. We have no evidence that selection for extremely long ears increases the yield above those of medium length. The difference in yield thus far has seemed to be due to a lessened yield resulting from the selection for short ears, rather than an increased yield from the selection for long ears.

2. THE RELATION OF SHAPE OF EAR TO YIELD

If there has been one ear character insisted upon more strongly than another in the corn judging of the country it has been that of cylindricity. In 1906 this Station began some studies of the relation of shape of ear, as regards cylindricity, to yield. In the selection of varieties to be used in these tests the aim was to include varieties having quite different tendencies; varieties in which the cylindrical ear predominated, and varieties in which the decidedly tapering ear was the rule. Accordingly, what I may call the Ohio, or old type of Leaming corn has been used throughout the test as representing the tapering varieties, and the Darke County Mammoth, another fairly distinct Ohio strain, as representing the varieties tending toward the cylindrical ear. During two of the four years of this test Reid Yellow Dent has also been included. Cylindrical and tapering ears from each variety have been compared side by side, selected to vary as widely in each direction as could well be found in corn that would pass at all for seed corn. A consultation of tables and illustrations will give an idea of the type of corn tested.



Leaming. Cylindrical and tapering ears.



Darke Co. Mammoth. Cylindrical and tapering ears.

TABLE V: The relation of shape of ear to yield, 1909.

Variety	Cylindrical or tapering	Average		A v. circum. 2 inches from		Yield per acre *Bus.
		Length Ins.	Weight Ozs.	Butt Ins.	Tip Ins.	
Leaming (b)	Cylindrical	8 1	11 4	7 2	6 3	93.71
Leaming (b)	Tapering	8.4	10 3	7 0	5 6	93.45
Gain for cylindrical ears						6.26
Darke Co. Mammoth (b)	Cylindrical	8 2	12.8	7.3	6.8	94 43
Darke Co. Mammoth (b)	Tapering	8.8	11 5	7.0	6 0	93 64
Gain for cylindrical ears						0.79
Reid Yellow Dent (c)	Cylindrical	9.3	13.8	7.2	6.5	90.08
Reid Yellow Dent (c)	Tapering	10.0	12.7	7 2	5.5	85.97
Gain for cylindrical ears						4.11
Leaming (c)	Cylindrical	8.2	12 0	7.7	6.5	88.46
Leaming (c)	Tapering	8 8	11 8	7.4	5.6	89.31
Gain for tapering ears						0.85
Average gain for cylindrical ears						1.08

(b) Second generation of cylindrical and tapering ears.

(c) First generation of cylindrical and tapering ears.

* Corrected to a uniform moisture content of 15 percent.

In Table V is given the result of the comparison of cylindrical with tapering ears in the tests of 1909. It will be discovered that the greatest variation in the character studied is found in the case of Reid Yellow Dent selections, and only in this variety is there a variation in yield of moment. This variation is in favor of the cylindrical ears.

TABLE VI: A study of the cylindrical and tapering ears reported upon in Table V, with reference to length, weight, shape, circumference and proportion.

Variety	Cylindrical or tapering	Excess in length Inches	Excess in weight Ounces	Excess in circum. (butt) Inches	Excess of butt circ. over tip circ. Inches	Excess in yield Bushels	Proportion of circ. to length Percent
Leaming (b)	Cylindrical		1 1	0 2	0 9	0 26	88.9
Leaming (b)	Tapering	0 3			1 4		83.3
Darke Co. Mammoth ..	Cylindrical		1 3	0 3	0 5	0 79	89.0
Darke Co. Mammoth ..	Tapering	0 6			1 0		79.6
Reid Yellow Dent	Cylindrical		1.1	0	0 7	4.11	77.4
Reid Yellow Dent	Tapering	0 7		0	1 7		72 0
Leaming (c)	Cylindrical		0 2	0 3	1 2		93 9
Leaming (c)	Tapering	0 6			1 8	0 85	84 1

(b) Second generation

(c) First generation.

The variation in the different ear characters of the variety types is brought out in Table VI, but this table offers little explanation of the results secured. While the cylindrical exceed the tapering ears in weight, the greatest excess in weight is not associated with the greatest excess in yield per acre.

TABLE VII. The relation of shape of ear to yield. Summary of 18 tests on 36 tenth-acre plots, 1906-1909.

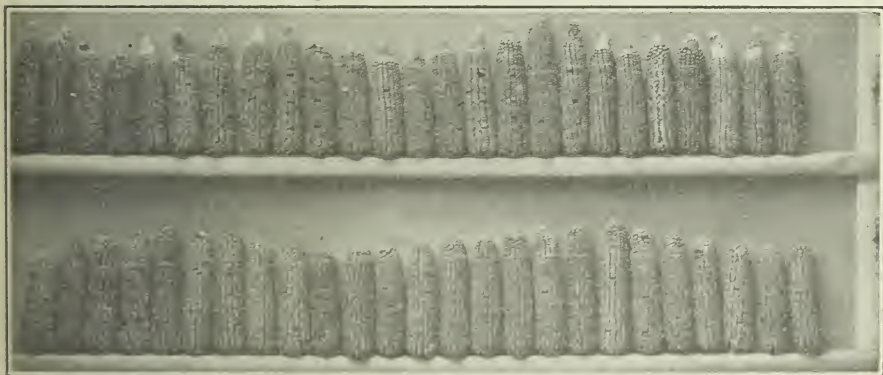
Year	Variety	Cylindrical or tapering	Yield of shelled corn per acre	Increase in yield
			* Bus.	Bus.
1909	Leaming	Cylindrical	91.08	
	Leaming	Tapering	91.38	0.30
	Darke Co. Mammoth	Cylindrical	93.43	0.79
	Darke Co. Mammoth	Tapering	93.64	
	Reid Yellow Dent	Cylindrical	90.08	4.11
	Reid Yellow Dent	Tapering	85.97	
Gain for cylindrical ears				1.08
1908	Leaming	Cylindrical	76.16	1.47
	Leaming	Tapering	74.69	
	Darke Co. Mammoth	Cylindrical	69.61	
	Darke Co. Mammoth	Tapering	71.51	1.90
	Gain for tapering ears			0.21
1907	Leaming	Cylindrical	59.81	
	Leaming	Tapering	60.92	1.11
	Darke Co. Mammoth	Cylindrical	63.74	2.64
	Darke Co. Mammoth	Tapering	61.10	
	Reid Yellow Dent	Cylindrical	60.49	
	Reid Yellow Dent	Tapering	60.91	0.42
Gain for cylindrical ears				0.37
1906	Leaming	Cylindrical	70.13	
	Leaming	Tapering	76.23	6.10
	Darke Co. Mammoth	Cylindrical	73.34	
	Darke Co. Mammoth	Tapering	76.72	3.38
	Gain for tapering ears			4.74
1906-09	Combined average of 18 tests, gain for tapering ears			0.87

* For 1909, ear corn corrected to 15 percent moisture.

In Table VII is given the summary of 18 tests, extending over four years. In two of these years the cylindrical ears lead slightly, while in two the tapering ears lead. The combined average shows a gain of 0.87 bushel in favor of the tapering ears. It is evident at a glance that there is not the consistent variation in yield in favor of either character that is found in the case of the long and short ears. In considering these data it seems that we are dealing with a character of minor importance, and hence the conclusion is forced upon one that until more decisive evidence is forthcoming, it is unwise to discriminate to any great extent in favor of either the tapering or cylindrical ear.

3. BARE VS. FILLED TIPS

In 1907 a test was started in which ears of Clarage corn having $\frac{3}{4}$ to $1\frac{1}{2}$ inches of bare cob at the tip of the ear were compared with ears completely filled out. In the ear-row tests of several years preceding it had been found that the high yielding ears were fully as apt to be bare at the tip as to be filled out, and accordingly the above test was started to study the relation of this character to yield in a larger way. The first year the average yield of the two plots planted with bare-tipped seed was 58.21 bushels, and of the plots planted with the filled-tipped seed, 57.79 bushels; a slight gain of 0.42 bushels for the bare tips.



Clarage. Filled and bare-tipped ears.

From each of these types 25 similar ears were selected for planting in 1908—bare tips from bare tips and filled tips from filled tips. The results the second year were in favor of the filled tips, with a gain of 1.45 bushel, the yields being 64.07 bushels for the bare tips and 65.52 bushels for the filled tips.

The selection was continued in like manner for the test of 1909, resulting in a gain of 2.19 bushels in favor of filled tips, the yields being 84.37 and 86.56 bushels per acre.

Tabulating the results for the three seasons' work, they stand as follows:

TABLE VIII: Three crops from bare and filled tips.

Year	Bare or filled tips	Yield of shelled corn per acre Bus.	Gain per acre Bus.
1907	Bare	58.21	
	Filled	57.79	
	Gain for bare tips.....		0.42
1908	Bare	64.07	
	Filled	65.52	
	Gain for filled tips.....		1.45
1909	Bare	84.37	
	Filled	86.56	
	Gain for filled tips.....		2.19
Average gain for filled tips			1.07

In the light of the above facts the tendencies of deliberate selection for bare tips would seem to be in the direction of a decreased yield. The yield of the original selections was slightly in favor of the bare tips, indicating that the foundation ears of the bare-tipped group were the equal, at least, of the filled-tipped. Their gradual falling off in yield as compared with the latter, seem to show the above mentioned tendency.

It is of interest to note the habit of these groups to reproduce their characteristic tip. The following table gives information regarding the seed ears used in 1909 and the crop procured therefrom.

TABLE IX: Bare tips vs. filled tips. Crop of 1909.

THE SEED USED.	BARE TIPS	FILLED TIPS
Average length of ear	8.4 ins.	8.0 ins.
Average weight of ear	9.4 ozs.	10.6 ozs.
Average circumference	6.6 ins.	6.7 ins.
Average percent of grain	53.6 %	84.5 %
THE CROP HARVESTED		
Yield per acre.....	84.37 bus.	86.56 bus.
Average length of ear	7.70 ins.	7.52 ins.
Average length of bare tips.....	1.03 ins.	0.53 ins.
Ears having filled tips	3.7 %	20.1 %

It will be observed that only 3.7 percent of the ears grown from the seed ears having bare tips had completely filled tips, while 20 percent of the ears grown from filled-tipped seed had completely filled tips. As might be expected the greater part of the ears and nubbins in both lots were bare at the tip. The sum total of inches of bare tips divided by the total number of ears harvested gives an average of 1.03 inch of bare tip *per ear* for the bare-tipped lot and 0.53 inch for the filled-tipped lot.

The average length of ear was greater by 0.18 inch in the case of the crop from the bare, as compared with the filled tips. If, however, we count only that portion of the ear length which is filled with grain, the filled tips lead by 0.32 inch.

Other things being equal, the continued selection of ears having $\frac{3}{4}$ to $1\frac{1}{2}$ inch of bare cob at the tip will tend to reproduce ears having this character, reducing the percentage of ears having filled tips, and to reduce the yield.

4. ROUGH VS. SMOOTH-DENTED EARS

The relation of the indentation of kernel to yield has been studied both in ear-row work, and also in plot work, in which rough and smooth types of the same variety were compared side by side. The results of the ear-row tests have been in favor of the smooth type, showing a gain of 2.84 bushels per acre over the rough type. The ear-row tests extend over a period of five years.

The plot work with these types was started in 1908. The results for the two years are as follows: For 1908, a gain of 0.99 of a bushel in favor of the rough-dented ears. For 1909, a gain of 2.17 bushels in favor of the smooth-dented ears. This reversal of results may be significant, or it may not. Two or three more years of this continuous selection will give some important information. The fact that the rough ears were superior the first season tested would indicate that they were inherently the equal of the smooth selections.

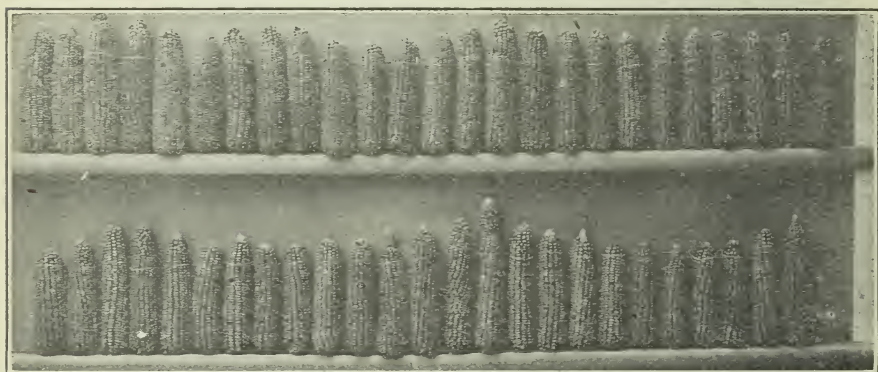
The character of the seed ears used in 1909 is recorded in the following table:

TABLE X: Rough vs. smooth-dented ears. Crop of 1909.

	ROUGH	SMOOTH
Average weight of ears	10.8 ozs.	9.6 ozs.
Average length of ears	8.3 ins.	8.1 ins.
Average circumference of ears	6.8 ins.	6.3 ins.
Average percent of grain	84.2	80 7
Proportion of circumference to length	81.9 %	77.7 %
Yield per acre	88.69 bus	90.86 bus

It will be noted that the rough-dented ears exceed the smooth in weight, length, circumference and percent of grain. Several of these characters, when studied under conditions in which they were dominant, have favored an increase in yield; but in a modified form, and associated with the more pronounced character of roughness in indentation, they have given way to the smooth type.

Taking into consideration both the ear-row and the plot tests, it seems that the evidence at present is in favor of the smoother-dented ears as being the more productive.



Clarage. Smooth and rough-dented ears.

5. HEAVY VS. LIGHT SEED EARS

As reported in Circular 71, this Station had found the heavier ears in its ear-row tests outyielding the lighter. This was for the years 1904-1906. Bringing this report down to 1909 these tests continue to tell the same story, the heavier ears giving a slight advance in yield.

It should be stated that extremes were not sought for in the selection of seed ears for this ear-row work, but in the selection of otherwise desirable ears there was some variation in weight. Of about 400 ears tested, if the heaviest 40 percent be thrown into one group and the lightest 40 percent into another, we find the average difference in weight of these two groups to be 2.46 ounces per ear, and the difference in yield to be 2.08 bushels per acre.

With the numbers involved and the varying conditions of growth during the different seasons it would seem that this variation in yield might safely be attributed to the variation in weight of seed ears.

In 1908 the Station started a tenth-acre plot test in which 50 representative heavy ears were compared with an equal number of lighter ears. The test was continued in 1909 with heavy ears selected from the crop grown from heavy ears in 1908 and with the light ears selected in a similar manner.

The yields for the two seasons' tests are as follows:

TABLE XI: Yields of heavy and light ears.

Year	Heavy or light ears	Yield of shelled corn per acre	Gain per acre
		Bus.	Bus.
1908	Heavy	65.73	
	Light	65.10	
	Gain for heavy ears.....		0.63
1909	Heavy	91.13	
	Light	87.80	
	Gain for heavy ears.....		3.23
Average gain for heavy ears.....			1.93

This plot test must continue longer before it will be safe to draw conclusions from it alone. Did it not confirm the ear-row tests of the past five years we should not have recorded it at this time. The two tests taken together, however, would seem to indicate a value for the heavy-weight ear. This sort of ear must not be confused with the overgrown and immature ear of large size.

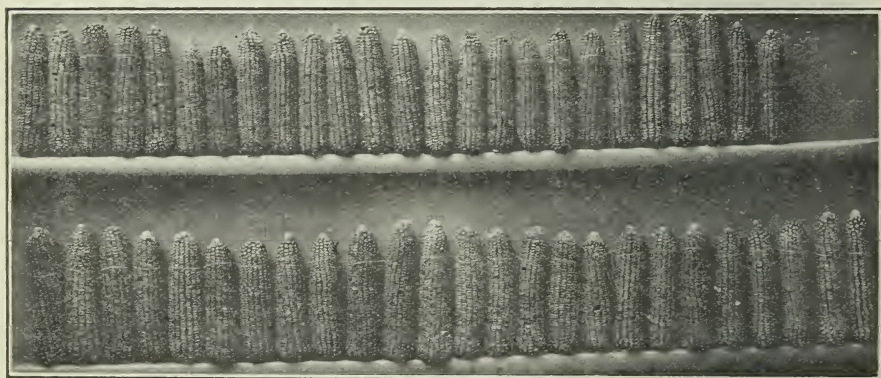
It will be noted that the heavy ears take a more decided lead in 1909. It is proper that the measurements of these two groups of ears as used in 1909 be recorded, that they may be compared with other ears used in the other tests. Also see illustration.

TABLE XII: Heavy vs. light ears. Crop of 1909.

SEED USED	HEAVY	LIGHT
Average weight of ears	11.6 ozs.	9.4 ozs.
Average length of ears.....	8.6 ins.	8.3 ins.
Average circumference of ears	6.9 ins.	6.2 ins.
Proportion of circumference to length	80.2 %	74.7 %
Average percent of grain	84.2 %	80.1 %
CROP HARVESTED		
Yield per acre.....	91.13 bus.	87.90 bus.
Average weight of ears	11.75 ozs.	11.03 ozs.
In computing the average weight of ears in the crop harvested, upwards of 1000 ears were included in each group.		

In considering the above data it will be noted that weight of ear and percent of grain both vary widely. It may be asked, which, if either, is responsible for the variation in yield? Our tests to date show that weight of ear is a better indication of high yielding seed ears than percent of grain.

For instance: If the same 400 seed ears above mentioned be divided into two groups, one containing the 40 percent having the highest percent of grain, the other the 40 percent having the lowest percent of grain, we find the former seed ears averaging 86.0 percent of grain and yielding 81.9 bushels per acre, and the latter averaging 81.8 percent of grain and yielding 83.1 bushels.



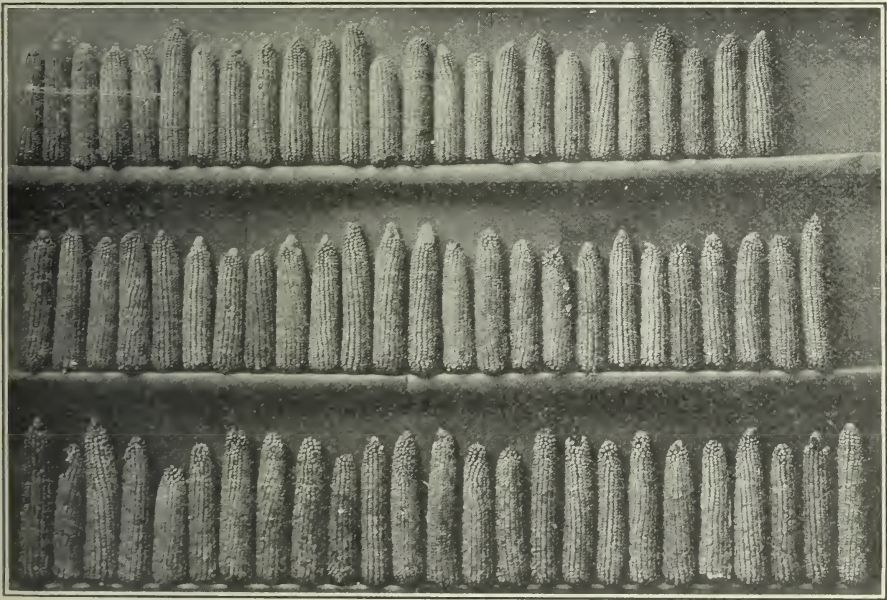
Clarage. Heavy and light ears.

In order to test this ear character under different conditions, a tenth-acre plot test was started this season, 1909. Two hundred fairly good seed ears were chosen. Each ear was shelled separately and its percent of grain determined. The 20 ears having the highest percent of grain were thrown into one group and the 20 having the lowest percent into another. The former averaged 86.09 percent grain and the latter 79.67 percent. The yield per acre as weighed from the field is 104.00 bushels for the high percent strain and 107.57 bushels for the low. At this writing we do not have the shelled corn records. This test will be continued, the selection of high and low percent grain being continuous.

For the present it may be said that weight of ear is worthy of attention in the selection of seed ears.

6. THE EFFECT OF THE PREVIOUS ENVIRONMENT OF CORN UPON ITS VALUE AS SEED

There have long been prevalent among corn growers quite definite ideas as to the propriety of taking seed corn grown under favorable conditions of soil to less favorable conditions, and vice versa. In order to study the effect of previous conditions of growth upon future crops, this Station began a test in 1907 in which seed corn selected in 1906 from the best manured plot in the fertility work of the Station was compared with corn from an adjoining unfertilized plot. It should, perhaps, be stated that the fertility plots mentioned have been under the same treatment—the one well manured for two crops of the 5-crop rotation, the other continuously unfertilized—for the past sixteen years.



From bottom to top: one, three and five plant strains.

The two lots of seed corn will be hereafter described as “rich” and “poverty” strains of Clarage corn. They were grown on plots side by side, under very favorable soil conditions in our regular variety test plots. In 1908 and 1909 new seed was secured from the original fertility plots and tested as in 1907.

Beginning in 1907 the rich and poverty strains have been grown upon the corresponding plots in the fertility work, the selection being continuous.

The results of the three tests thus far conducted are not convincing. In 1907 the poverty strain led by 0.98 bushel. In 1908 the rich strain by 2.32 bushels. In 1909 the poverty strain led again by 3.80 bushels. The average gain for the poverty strain is accordingly 0.82 bushel per acre.

Attempting to get an answer to the same question from another angle, this Station has been comparing seed ears selected under conditions of normal stand with ears selected without knowledge of stand, i. e., from the wagon. In each instance the best seed ears readily obtainable were selected. Averaging the tests of 1906-1908, the seed ears selected under normal stand have given an increase in yield of 2.36 bushels per acre.

In 1909 this test was changed to make possible more accurate knowledge as to the conditions of stand. Seed ears for use in this work were selected from the "thick and thin" planted plots of 1908. For this use the twenty-five largest and best ears obtainable were selected from the plots upon which corn was growing at the rates of one plant per hill, three plants per hill and five plants per hill. These three lots of seed known as the one, three and five plant strains were planted on adjoining plots and in duplicate. The conditions of growth in 1909 were made as uniform in every way as possible. Interplanted with these three strains were the regular check plots. The yields given in the table below are corrected to a moisture content of 15 percent.

TABLE XIII: One, three and five plant strains of corn. Crop of 1909.

Strain	Average weight of ears Ounces	Average length of ears Inches	Average circum. of ears Inches	Proportion of circum. to length Percent	Average percent of grain	Yield per acre Bus.
One plant	12.0	9.4	6.9	73.4	82.5	91.49
Three plant.....	10.0	8.8	6.6	75.0	84.0	91.74
Five plant	8.0	7.9	6.3	79.7	82.5	92.58

The differences in yield are of course slight. It is of interest to note, however, that seed ears which are inferior in size and appearance (see illustration as well as table) because of environment are not necessarily inferior in hereditary value. It would seem to be important to know something of the conditions under which an ear of corn is grown before undertaking to tell very much about its value as a seed ear.

In the latter test, as in the rich and poverty strain test, it is evident that under the unfavorable conditions of fertility or stand the ears will be small, and few or none grade as seed ears. May it not be possible, however, that if the cream be skimmed off, one will get a higher quality of seed after all? Whether nature, under "the survival of the fittest," will bring to the front individuals of superior merit, or not, remains for future tests to determine.

7. THE GERMINATION BOX AS AN INDEX TO HIGH YIELDING EARS

It is a fact well known to everyone who has conducted germination tests with corn that the kernels from some ears germinate much quicker than from others; that in a group of 100 ears, not infrequently a half dozen or more will be out of the soil, and an inch or two high before the laggards appear above ground. Is this precocity an indication of superiority as regards yield? Will the "first ups" out yield the "last ups?" If they could be depended upon to do so, as has sometimes been asserted, the germination box could be substituted for the ear-row test, and not only much labor be saved, but more rapid strides taken in the direction of corn improvement.

In order to turn light upon this question a test was conducted in 1907. Six hundred ears were germinated in a shallow box filled with clay loam soil, the kernels being covered with an inch of soil. Data were gathered regarding the order of the appearance of the plants above ground twice in 24 hours. In each lot of 150 ears the 10 ears which came through the soil first were put in one class and the 10 which came up last in another class. Only those ears were considered of which every kernel planted grew. The average variation in the appearance of the plants above ground of the two lots was 48 hours.

A composite sample of seed was made up representing each ear, and two tenth-acre plots were planted from each lot.

The yields of these plots were as follows:

TABLE XIV: First ups and last ups.

CLASS	YIELD OF SHELLED CORN PER ACRE
Plot No. 46 First ups.	63.71 Bushels
Plot No. 47 Last ups.	66.90 "
Gain for Last ups.	3.19 "
Plot No. 50 First ups.	66.66 "
Plot No. 51 Last ups.	62.16 "
Gain for Last ups.	2.50 "
Average gain for Last ups.	2.84 "

The same differences in the rapidity of germination were noted in the field as in the germination box. These differences appear to be due to the comparative hardness of the kernels from the different ears and their consequent capacity for rapidly absorbing moisture. The larger the proportion of soft, white starch in the kernel the more rapidly it takes up water and the sooner it germinates. Variation in the thickness and imperviousness of the hull may have something to do with it also.

The germination box is exceedingly useful in weeding out ears injured by the careless handling of seed corn. The more nearly the conditions of growth in the box conform to field conditions, the more valuable will be the test. Further than this the germination test seems to have little value.

As a matter of experiment in its ear-row tests, this Station has found that where enough seed has been planted so that a uniform stand of plants could be had by thinning, a considerable falling off in percent of germination in individual ears has been no sure indication of inferiority in yield. Dividing the ears tested in its ear-row work for the last five years into two classes, in one putting that 40 percent of the ears showing best germination, and in the other the 40 percent showing poorest; the average yield of the two lots has varied but .68 of a bushel. This variation is in favor of the lot showing the best germination.

8. ADAPTABILITY: OF FIRST CONSIDERATION IN THE SELECTION OF SEED CORN

This is true as applied to varieties, and to individual ears within a variety. The loss Ohio corn growers sustain by purchasing unacclimated and ill adapted varieties of corn for seed uses is very great. It is to be feared that the stimulus given the seed trade by the corn shows, with their high prizes, is increasing the trouble from this source. As illustrating the losses incident to the use of varieties not acclimated to the locality where grown, attention is called to the following table which gives the yield per acre, together with some idea of the quality of the product, of seven different varieties as grown at this station in 1908. Similar results are occurring every year in our variety test work and are duplicated upon many corn farms in every county in this state.

TABLE XV: Variation in adaptability of different varieties of corn; 1908.

Variety	Date of tasseling	Average height of plants Ft. Ins.	Percent of moisture as husked	Bushels of shelled corn per acre	Weight per bu. of shelled corn Lbs.	Pounds of stover per acre
Hildreth Yellow Dent, Kansas.....	Aug. 8	11-6	33.7	57.69	49.00	6,720
Reid Yellow Dent, Illinois	Aug. 1	10-6	25.0	67.19	50.00	4,700
Reid Yellow Dent, Southern Ohio	July 30	10-0	22.4	69.91	50.50	4,240
Darke Co. Mammoth, Southern Ohio.....	July 28	9-10	21.0	73.12	53.50	4,167
Leaming (early strain) Southern Ohio.....	July 27	9-9	20.7	71.78	52.50	3,770
Ohio 84-6055, O. A. E. S.....	July 24	9-10	18.7	78.76	54.50	3,760
Clarage, O. A. E. S.	July 24	9-6	17.8	68.07	54.50	3,533

The above table calls for little comment. While the figures given seem to discourage the introduction of new varieties, they apply to the wholesale introduction only. It is possible to try out new varieties of promise in a small way, and by the careful selection of ears from plants which come nearest to being adapted to local conditions, to gradually acclimate any variety which seems to have merit.

The variation in individual plants which makes this sort of improvement possible will be appreciated by any one who has conducted an ear-row test and kept records regarding the data recorded in the following table:

TABLE XVI: Variation in individual ears of the same variety as judged by their progeny in ear-row work; 1909.

Ear number	Date of tasseling	Date of silking	Height of plant Ft. Ins.	Height of ears Ft. Ins.	Percent of moisture at husking	Yield per acre corrected to 15% M. Bus.
9002.....	July 30	Aug. 4	10-2	4-2	30.8	86.30
9067.....	July 23	July 28	7-5	2-6	23.0	50.84
9015.....	July 29	Aug. 4	9-10	3-11	31.6	77.13
9025.....	July 22	July 27	8-8	3-2	25.2	76.16
9011.....	July 28	Aug. 4	9-2	4-0	32.9	93.19
9063.....	July 24	July 29	8-4	3-3	24.8	67.17
9016.....	July 30	Aug. 4	9-8	4-7	32.1	87.08
9007.....	July 24	July 29	8-9	3-0	26.9	91.64
9061.....	July 28	Aug. 1	9-7	3-9	29.2	73.61
9056.....	July 23	July 29	8-1	3-4	28.5	68.35
9013.....	July 28	Aug. 2	8-8	3-6	27.0	80.02

The Ohio farmer should grow in a large way only such varieties as have proved their worth for a series of years under such conditions as prevail in his immediate locality. If satisfactory native varieties are not obtainable, approved new varieties may be tested in a small way and gradually adapted to local needs as indicated.

9. A FULL STAND OF PLANTS

The importance of having a full stand of plants is appreciated by more corn growers than have yet been able to attain it. As to what constitutes a full stand, there is a considerable difference of opinion. This difference of opinion is, to some extent, a difference of fact, for under different conditions of soil and climate different stands are needed. And yet it is probable that much of this difference of opinion is mere opinion, without any basis of fact.

TABLE XVII: Thick and thin planting of corn.

No. plants per hill	Average weight of ears	Percent of		Yield of shelled corn per acre	Pounds stover per	
		Nubbins	Barren plants		Acre	Bushel of corn
1904						
1.....	.635	11.5	1 8	30.79	1,750	56.8
2.....	.578	21.3	1.9	48.77	2,500	51.3
3.....	.557	21.1	3.9	60.46	3,610	59.7
4.....	.502	27.1	5.1	65.40	3,775	57.7
5.....	.431	37.1	10.3	59.73	4,090	68.5
1906						
1.....	.701	7.7	2 6	33.01	2,680	81.2
2.....	.676	9.9	2 3	59.68	3,870	64.9
3.....	.594	15.7	2.9	73.96	4,350	58.8
4.....	.507	25.2	5.7	78.47	4,580	58.4
5.....	.429	42.8	9 6	78.14	5,500	70.4
1907						
1.....	.763	10.1	1.9	28.76	2,848	99.0
2.....	.623	19.6	3 2	41.14	3,791	92.2
3.....	.474	34.3	7.9	40.09	4,147	103.4
4.....	.405	48.0	15.9	39.09	5,437	113.5
5.....	.354	58.5	24.5	35.91	5,695	158.6
1908						
1.....	.627	11.8	2 6	33.32	2,660	79.8
2.....	.625	12.5	2.0	51.47	3,400	66.1
3.....	.549	6.9	1.1	62.62	3,870	61.8
4.....	.459	13.4	2.9	64.85	4,190	64.6
5.....	.395	21.0	2 9	67.40	4,590	68.1
1909						
1.....	.740	18.1	1.1	*37.67	3,300	88.4
2.....	.780	8.8	0.8	66.57	4,710	70.8
3.....	.710	11.6	1.8	85.30	5,670	66.5
4.....	.622	12.6	5.3	93.78	6,300	67.2
5.....	.565	20.6	6.9	102.96	6,990	67.9

* Yield for 1909 in ears reduced to a 15 percent moisture content.

As a guide for such conditions as those which obtain at this Station, namely, a silt loam soil of the Waverly series, manured on a clover sod with 8 to 12 tons of phosphated manure from the stable or manure shed, the following table is inserted giving the yields of shelled corn per acre at thicknesses of planting ranging from one to five plants per hill, in hills 42 inches apart each way, for five different seasons, and the average of four seasons' tests. The year 1909 is omitted from the average since the shelling records are not yet available.

In these tests sufficient seed was planted that exact stands could be secured by thinning.

TABLE XVII: Continued. Average for four years, 1904, '06, '07, '08.

No. of plants per hill		Average weight of ears	Percent of		Yield of shelled corn per acre	Pounds stover per	
Hill	Acre		Nubbins	Barren plants		Acre	Bushels of corn
1	3,555	.68	10.3	2.2	31.47	2,484	78.9
2	7,110	.621	15.8	2.4	50.26	3,390	67.4
3	10,665	.545	19.5	4.0	59.28	3,994	67.4
4	14,220	.463	28.4	7.4	61.95	4,495	72.6
5	17,775	.402	39.8	11.8	60.29	4,969	82.4

It will be noted that the highest average yield of corn has been secured from four plants per hill, or 14,220 plants per acre. That five plants per hill have given a higher yield than three; however the average size of ears is much smaller and the percent of nubbins very large. For some uses this would be a disadvantage, but for shock feeding the small ears and the finer stover would be acceptable.

Very extensive tests with different distances between hills, and different numbers of plants per hill, have been conducted by the Illinois Experiment Station. The average of their large number of tests in six different localities in Illinois shows the highest yields to have been secured from an average stand of 11,107 plants per acre, and the second highest yields from 12,130 plants per acre.

Stands of 12,400 plants per acre may be had from three plants per hill, in hills 36x42 inches. With present information this may be regarded as perhaps a full stand for good soil conditions.

SUMMARY

While the tests herewith reported will be continued indefinitely, with some modifications, for the present they seem to show:

1. That the selection of seed ears of less than normal length, for a given variety or locality, will reduce the yield and, if the selection be continuous, gradually shorten the length of ear.

2. That shape of ear as regards cylindricity is a matter of less importance than many other of the prominent ear characters. While the tapering ears have, upon the average, led slightly in yield, the variation is neither important nor consistent, and more evidence is needed before a pronouncement can be made for either type.

3. That the continuous selection of seed ears having an inch to an inch and a half of bare cob at the tip will increase the average amount of bare cob at the tip, diminish the total number of ears having completely filled tips, and decrease the yield of shelled corn per acre.

4. That so far as indentation of kernels is concerned, ears comparatively smooth—crease-dented—have proved somewhat superior in yield to the rough-dented ears.

5. That, conditions of growth being equal, weight of ear, as made up of slight increases in length, circumference and amount and density of grain and cob, favors an increase in yield and is worthy of consideration in the final selection of seed corn.

6. That a knowledge of the previous conditions of growth is helpful in estimating the value of seed corn. And further, that seed for use under given conditions would better be selected under slightly inferior, rather than a very much superior environment.

7. That the germination box can hardly be expected to pick out seed ears of superior hereditary merit. Its work is completed in atoning, in part, for carelessness in the handling of seed corn.

8. That the main crop of corn on every farm should be planted with varieties known to be productive and acclimated, and that importations of seed corn from a distance should be confined to a very limited area until, by careful selection, they have become adapted to local conditions.

9. That a maximum yield of corn can hardly be secured under good soil conditions in this state with less than 12,000 plants per acre. This stand may be had with three plants per hill, in hills 36 inches by 42 inches.

PREFACE

The feeding experiments on which this bulletin is based were conducted by the author at the Missouri Experiment Station in the years 1905 and 1906, and the results prepared for publication immediately thereafter.

The chemical data are principally the work of Dr. Paul Schweitzer, Dr. R. M. Bird and Mr. F. W. Liepsner, all of whom were connected with the Missouri Station at the time the work was done. The author acknowledges with much gratitude his indebtedness to these chemists, and also to Dr. C. W. Greene and Dr. W. Koch for courtesies enjoyed in their laboratories.

Certain additions to the chemical data are now made from the work of Mr. A. C. Whittier and the author, at the Ohio Experiment Station; the discussion is revised, and the bulletin is published at the Ohio Experiment Station, and issued simultaneously by the Missouri and Ohio stations.

BULLETIN

OF THE

Ohio Agricultural Experiment Station

NUMBER 213.

DECEMBER, 1909

SPECIFIC EFFECTS OF RATIONS ON THE DEVELOPMENT OF SWINE

By E. B. FORBES

INTRODUCTION

The characters of growing animals are determined by the limitations imposed by inheritance and the food supply. Inheritance furnishes detailed plans and specifications; food builds and maintains the structure.

Deficiencies in the amount and kinds of nutriment available may affect not only the size, but also, within limits, the character of the growth of animals, just as shortage of certain building materials would affect the size and style of construction of a building.

The animal body is constructed from fourteen chemical elements. Not all foods contain all of these substances in amounts sufficient to sustain growth. Many of our by-product foods are abnormal and require knowledge and judgment in their use for animals; and Indian corn is, in a number of ways, deficient as a food for growing animals.

In the hands of stock breeders corn proves to be a poor producer of bone and muscle, and animals fed too little else along with their corn are apt to be lacking in size. The professional herdsman, and also many of the successful breeders of pure-bred stock of all kinds, believe that corn is injurious to breeding animals. We believe, however, that there is no time in the life of any farm animal in the Corn Belt when corn may not properly be used, whether it be with a fast horse or a slow one, a milch cow or a bacon hog, a laying hen or a breeding ewe; but for many purposes it must be used in moderation, and must be properly supplemented, so as to provide those nutrients in which it is deficient. Animals need energy-producing food, much more of it than of any other sort, and in this region corn will supply this kind of nutriment more cheaply than will any other food.

The specific effects of foods on growing animals appear to be due very largely to the mineral elements which they contain.¹

The influence of these constituents on the relative development of fat, bone, muscle and visceral organs and on the qualitative composition of these tissues is, however, practically an unworked field, and appears to give promise of yielding much valuable information.

When the live-stock feeder shall have become thoroughly a master of his business, he will know the specific or characteristic effects of the foodstuffs which he uses, on the animals consuming them, just as the physician who is learned in therapeutics knows the specific actions of the drugs which he administers.

The fact that foodstuffs do have these specific effects on animals was demonstrated many years ago by J. W. Sanborn² of the Missouri Agricultural College. Subsequent work by Henry³, and Shelton⁴, along this same line confirmed Sanborn's conclusion, that rations containing more protein than does Indian corn produce more muscular growth. These writers, however, made no mention of the mineral constituents of the foodstuffs used.

In compounding the rations fed in these various experiments, these authors apparently sought only to vary the proportions of the nitrogenous and non-nitrogenous organic nutrients without reference to mineral or ash constituents. It is true, however, that in these rations the nitrogenous and mineral constituents varied together so that the high-protein rations happened also to be high in ash constituents; hence there is hardly warrant for assuming that the proteid compounds alone are responsible for the effects observed on the relative development of fat and muscular tissue.

This above-mentioned work has been quantitative only, in so far as the various tissues are concerned, except in that Henry, Shelton, Carlyle⁵ and Burnett⁶, have observed the fact that the ash constituents of foodstuffs profoundly affect the ash content and breaking strength of the bones of hogs consuming them.

Numerous investigations, especially those of Shutt of Canada, have also proven that the fat of hogs is susceptible of chemical modification through the use of ordinary foodstuffs.

In considering the significance of variations in the size of organs, and the development of tissues, one should bear in mind that all of the so-called vital organs together, including the nervous system, contain very much less substance than the remaining less essential

¹ See Ohio Bul. 201, page 132.

² Bul. 10, 14, 19, Missouri Agricultural College.

³ Annual Reports, Wis. Agr. Exp. Sta., 1886, '87, '88, '89.

⁴ Bul. 9, Kans. Agr. Exp. Sta.

⁵ Bul. 104, Wis. Agr. Exp. Sta.

⁶ Bul. 94, 107, Neb. Agr. Exp. Sta.

parts; and rations which are so abnormal as to be inadequate to the necessities of these vital organs are very much more rare in practice than rations which would not contain sufficient nutriment, in excess of the demands of the vital organs, to support maximum development of the less essential parts. Hence it is especially in the development of the less essential fat, bones and muscles that we find the more noticeable specific effects of rations rather than in the development of the vital parts. These more important and carefully guarded vital organs are, of course, dependent in the end on the food supply just as are the less important ones which may serve them as stores of nutriment, and in especially compounded rations we have been able, in experiments at the Ohio Station, to modify even the chemical composition of the brain by withholding from the animal, phosphorus in the particular condition required by this organ.

These and other vital organs are maintained in condition to do their work, whether there be nutriment enough to support maximum development of the less essential organs or not; in fact, the wellbeing of the more important organs is maintained at the expense of the less important whenever insufficiency of nutrients makes this necessary. Thus fatty tissue is of less functional value to the animal than most others, and hence is sacrificed whenever the maintenance of more important tissues requires it. Muscular tissue also may be used up to such extent that the animal becomes much emaciated, in the maintenance of more important tissues in condition to perform their work.

The maintenance of the neutrality of the blood and tissues is of greater importance than the growth of the bones, and hence we find bony substance sacrificed whenever its carbonates are needed to neutralize a dangerous excess of mineral acid. In pregnant animals we find the same principle evidenced in the capacity of the foetus to rob the mother of any such nutriment as its development requires.

The size of the visceral organs is regulated, in part, in accordance with the principle that they take from the blood-stream such nutrients as they require to carry on the work imposed upon them. Departures from the average development in the directions either of increase or decrease may, therefore, be considered as partially determined by the amount of work which has been required of the organs in question, especially if these organs remain normal in composition, and partially by the capability of the food to cause gain of the sort required.

The following bulletin contains in addition to economic data, the beginning of a series of studies of the effects of foodstuffs on animals. It consists of the results from three experiments, the conclusions from the first beginning on page 266, and from the second and third on page 295. A general summary of results is to be found on pages 301 to 305.

EXPERIMENT I

Objects. The objects of this experiment were (1) to compare wheat middlings, linseed oil meal, soy beans, tankage and germ oil meal as supplements to corn in the dry-lot fattening of hogs for market; (2) to compare full-feeding on these rations with the feeding of restricted amounts; and (3) to observe the effects of these rations on the composition of the flesh.

Method of experimentation. This experiment was conducted during the months of April and May, 1905. There were in all sixty-five hogs used in this experiment. They were divided into thirteen lots of five each. One of these lots was killed at the beginning of the experiment and the carcasses were subjected to all the tests which were later applied to the hogs in the experiment proper, this lot constituting the check or basis of comparison for the lots which were fed.

These hogs were all grade Poland Chinas and were about seven months of age at the time the experiment began. They weighed about 120 pounds each and were in good, thrifty growing condition. All had run upon bluegrass pasture during the preceding winter, and had received nothing but corn and water in addition to the feed which they picked up. They were a uniform lot and were fairly good in quality. The same proportion of gilts and barrows was kept in each experimental lot. These hogs were fed in small pens with cement floors, the sheds sheltering them being open on the south. On account of the fact that these hogs had all received the same treatment before they went into this experiment, they were given only one week's preliminary feeding in the experimental sheds.

The first weights were taken on April 1, before the evening feed, and all subsequent weights were taken, as in this case, before giving the evening ration. With their first experimental feed they were given medicine for the purpose of expelling any such intestinal parasites as they might have with them. This procedure has been adopted as a standard method of operation in our feeding experiments, because we find that round-worms are so exceedingly common in swine that a feeding experiment undertaken with animals which have not been freed from these parasites is not at all certain to give accurate results. The dose administered in this case was

three grains of santonin and five grains of calomel for each 80 pounds of live weight. This has proven to be an especially effective remedy.

The hogs were fed twice daily, at regular times. All feed was ground into a moderately fine meal, and fed wet with water, until just thin enough to pour handily. Nothing in the way of ashes or charcoal was given to any lot, but salt was regularly administered with the grain, to the amount of one ounce per head per day. The hogs were watered regularly after feeding, and after the weather became warm, a third time at noon. The experiment progressed from start to finish without any accident or sickness to detract from the reliability of the results. The weather throughout the whole of the experiment was ideal for our purpose.

TABLE I: RATIONS USED

LOTS	RATIONS	AMOUNTS FED
1	Corn meal	Ad libitum.
2	{ Corn meal, 18.25 percent; wheat middlings, 81.75 percent	“ “
3	{ Corn meal, 82.21 percent; linseed oil meal, 17.79 percent	“ “
4	{ Corn meal, 80.43 percent; soy beans, 19.57 percent	“ “
5	{ Corn meal, 91.94 percent; tankage, 8.06 percent	“ “
6	{ Corn meal, 60.64 percent; germ oil meal, 39.36 percent	“ “
7	Corn meal	“ “
8	{ Corn meal, 18.25 percent; wheat middlings, 81.75 percent	1.084 lbs. for each pound eaten by Lot 7.
9	{ Corn meal, 82.21 percent; linseed oil meal, 17.79 percent	1.0214 lbs. for each pound eaten by Lot 7.
10	{ Corn meal, 80.43 percent; soy beans, 19.57 percent	1.016 lbs. for each pound eaten by Lot 7.
11	{ Corn meal, 91.94 percent; tankage, 8.06 percent	1.016 lbs. for each pound eaten by Lot 7.
12	{ Corn meal, 60.64 percent; germ oil meal, 39.36 percent	1.01 lbs. for each pound eaten by Lot 7.
13	Check lot; killed at beginning of experiment.	

The nutritive ratio was the same, 1:6.5, in each case except where corn was fed alone as to Lots 1 and 7.

As will be seen by inspection of the above table, there were twelve lots of hogs fed in this experiment. The thirteenth lot, to which we shall refer throughout the bulletin as the “check lot,” was killed just as the other twelve went on feed, this one furnishing us a basis for judgment as to the changes produced during the fattening process. Lots 1 to 6 were fed on the same rations as Lots 7 to 12, the only difference being that the first set were fed to the limit of their appetites, while in the second set each lot was given just such amount of feed as was necessary to provide the same number of pounds of digestible nutriment as was consumed by Lot 7, which

received corn alone, *ad libitum*. All of these rations, except those consisting of corn meal alone, were so compounded that the nutritive ratio, or proportion of proteid to non-proteid organic nutriment, was as 1:6.5; hence it is seen that Lots 1 to 6 furnish us evidence as to the comparative usefulness of these rations as ordinarily fed, while Lots 7 to 12 show us the comparative value of the same amounts of digestible organic nutriment in the same nutritive ratio, but from different sources.

Corn meal was fed in both series as a standard ration. Corn meal and wheat middlings were used in rations Nos. 2 and 8, because of the high esteem in which middlings is held by pork producers the country over. In order to get a ration having a nutritive ratio of 1:6.5, it was necessary to feed the middlings in larger proportion to corn than that in which we ordinarily use this feed for profit.

Rations 3 and 9 are composed of corn and linseed oil meal, a combination which we have found especially efficient and economical. Rations 4 and 10 are composed of corn meal and soy beans. Soy beans were used because they constitute the only concentrated, nitrogenous, grain supplement to corn which we commonly find it profitable to produce on the farms of this region.

Rations 5 and 11 are composed of corn meal and digester tankage. This supplement has an advantage over many others in that its greater concentration renders it unnecessary that it be handled in such large quantities as the grain supplements. Tankage is dried and ground meat scrap, with most of the fat removed.

Rations 6 and 12 are composed of corn meal and germ oil meal. This supplement is a by-product from the manufacture of glucose from corn. We used this feed in order to balance the corn ration with a corn product. This combination gives us an interesting ration to compare with those in which the corn is balanced by food-stuffs produced by other plants.

TABLE II: CHEMICAL COMPOSITION OF FEEDS USED
IN EXPERIMENT I

Feeds	Water	Protein Nx6.25	Nitro- gen-free extract	Crude fiber	Ether extract	Ash	Phos- phorus	Leci- thin
	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
Corn meal.....	15.87	8.06	69.06	1.92	3.64	1.45	.235	.111
Wheat middlings.....	12.77	14.19	59.26	5.60	4.53	3.65	.901	.739
Linseed oil meal. ...	9.32	31.31	41.85	8.02	4.50	5.00	.81	.922
Germ oil meal.....	10.50	19.69	49.27	8.52	9.17	2.85	.74	1.042
Soy beans.....	10.87	30.13	31.90	4.15	17.65	5.30	.745	1.827
Tankage.....	7.90	54.00	.....	....	10.44	22.25	3.238	1.126

This table sets forth the chemical composition of the food stuffs used. It will be noted that the corn meal contained rather more moisture than this foodstuff usually carries in the spring. It was also rather low in protein and in fat. The wheat middlings was low in protein and high in fiber, ash and phosphorus. Its appearance and composition strongly suggested ground bran. The linseed oil meal was bought for the "old process" article, but the oil content was low. The germ oil meal was in every way typical of this by-product as usually found on the market. Its high oil content makes it necessary that it be fed with care, especially since it also necessitates its being fed in large proportion with corn, if used as a supplement to this feed. The soy beans were particularly rich in fat, and were also about as rich in protein as was linseed oil meal. The tankage contained 54 percent of protein. The carbohydrate material present was not determined. It will be observed that the ash content of the vegetable foodstuffs used ranged from 1.45 percent in corn meal to 5.3 percent in soy beans, but that the tankage contained 22.25 percent. Its high ash content was due largely to the fact that it contained a considerable amount of bone.

The lecithin content of these feeds was considered because of the interesting relation of lecithin to certain tissues in the body.

Lecithin is a wax-like substance composed of fat, glycerophosphoric acid and a nitrogenous group called choline. It is found in all plant and animal cells, and its abundance in gland cells and in the germs of seeds, which contain great numbers of cell nuclei, suggests that it is a nuclear constituent. It is also abundant in the sexual elements, in eggs and in the nervous system. Its relation to living processes is apparently important, but its significance is as yet not understood.

Lecithin is a highly valuable nutrient, because of the wide range of its usefulness. Its importance as a constituent of the food depends on whether or not the animal can build up lecithin from other phosphorus compounds. This question is not yet finally settled.

TABLE III: DIGESTIBILITY OF FEEDS USED

Feeds	Number of trials	Dry matter	Protein (Nx6.25)	Crude fiber	Nitrogen-free extract	Ether extract	Authority
		Percent	Percent	Percent	Percent	Percent	
Corn.....	4	92.0	86.0	40.0	95.0	76.0	Wolff
Wheat middlings.....	2	76.5	76.2	48.2	86.2	94.5	Minn. Sta.
Linseed oil meal.....	2	77.5	86.0	12.0	85.0	80.0	Minn. Sta.
Germ oil meal*.....	4	92.0	86.0	40.0	95.0	76.0	Wolff
Soy beans**.....	1	81.9	91.1	71.2	76.3	85.7	Mass. Sta.
Tankage***.....			97.0			87.0	Wolff

* Assumed same as corn.

** Digestibility with sheep.

*** These coefficients determined for meat meal.

Our knowledge of the digestibility of even the commonest food-stuffs for swine is exceedingly scanty. We have assumed that the digestibility of the different nutrients in germ oil meal was the same as in the corn from which this foodstuff was made. The only digestion experiments with soy beans, known to us, were conducted with sheep at the Massachusetts Station, and these figures were used in this experiment. Since we had no digestion tests with tankage, we were obliged to assume that the protein and the ether extract in this feed have the same digestibility as in meat meal, upon which Wolff conducted a digestion experiment many years ago. Recent work by Dietrich of the Illinois Station indicates that the figure used for digestibility of protein in tankage is too high. The digestion coefficients which we have used for corn, were also determined by Wolff. The digestion coefficients of linseed oil meal and wheat middlings were made at the Minnesota Experiment Station.

Some of the assumptions above noted are unwarranted, and doubtless introduce errors into our work, but are believed not to be grossly misleading. Accuracy would have required that digestion experiments be conducted in connection with the test, but this was not possible.

TABLE IV: NUTRIENTS IN ONE HUNDRED POUNDS OF RATIONS AS COMPOUNDED

Lots	Feeds	Digestible protein	Digestible carbohydrates	Digestible ether extract	Phosphorus	Lecithin
		Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
1	Corn meal.....	6.93	66.37	2.77	.24	.11
2	Corn meal;.....	1.26	12.11	.51	.04	.02
	wheat middlings..	8.84	43.97	3.50	.74	.60
	Total.....	10 10	56 08	4 01	.78	.62
3	Corn meal;.....	5.70	54.56	2.28	.19	.09
	linseed oil meal....	4.79	6 50	.64	.15	.16
	Total.....	10 49	61 06	2 92	.34	.25
4	Corn meal;.....	5.57	53.38	2.23	.19	.09
	soy beans.....	5.37	5.34	2.96	.15	.36
	Total.....	10 94	58 72	5 19	.34	.45
5	Corn meal;.....	6.37	61.02	2.55	.22	.10
	tankage.	4.22		.73	.26	.09
	Total.....	10 59	61 02	3 28	.48	.19
6	Corn meal;.....	4.20	40.25	1.68	.14	.07
	germ oil meal.....	6.66	19.76	2.74	.29	.41
	Total.....	10 86	60 01	4 42	.43	.48

It must be borne in mind that the specific effects of each of these rations is dependent on the proportions in which the constituent foodstuffs are present. The characteristic effects of the rations containing wheat middlings and linseed oil meal, for instance, depend on the presence of these supplements in a particular proportion. Linseed oil meal contains considerably more lecithin than does wheat middlings, but the ration containing the oil meal contains very much less lecithin than the one containing the middlings; this because the oil meal was fed in so much smaller proportion to the corn than the middlings. Hence it is well to bear in mind that we are observing the characteristics, not of individual foodstuffs, nor of chemical compounds, but of *rations*. This gives an especial significance to Table IV, page 246.

The corn ration, compared with the others, is low in protein, in phosphorus and in lecithin, but high in carbohydrates.

The wheat middlings ration is the least concentrated of all, since it contains the highest percentage of indigestible fiber. It contains more phosphorus and lecithin than any other ration.

The remaining four rations are about equally concentrated, though the linseed oil meal and soy bean rations contain less phosphorus than the tankage and the germ oil meal rations. The soy bean ration also contains less starch and more fat than the tankage and the linseed oil meal rations.

The palatability of these rations is indicated by the amounts eaten by Lots 1-6. (Table V, page 248.) Many have considered corn to be more palatable to hogs than other foodstuffs, but these hogs ate less of the ration of corn alone than of any other except the ration of corn and germ oil meal. This last was a hard ration to feed. In general it was more palatable than corn, but after eating of it heartily for several days, the pigs would suddenly go off feed badly. It was hard to get their measure. The germ oil meal is bulky when wet, swelling through the absorption of a large amount of water. While it may be useful as a component of a more varied ration it was not satisfactory as a single supplement to corn.

It seems likely that the unsatisfactory character of this ration was due to the fact that all of its proteids came from corn.

Animals construct the proteids of their bodies from proteids only. The food proteids, however, cannot be built up into animal tissues until they have been split up into the primary nitrogenous groups from which they are composed, and then rearranged and reunited to form the particular compounds required by the animal.

TABLE V: TOTAL NUTRIENTS FED

Lots	Rations	Total feed consumed	Digestible protein	Digestible carbohydrates	Digestible ether extract	Phosphorus	Lecithin
1	Corn meal.....	Lbs. 1292.5	Lbs. 89.57	Lbs. 875.83	Lbs. 35.80	Lbs. 3.04	Lbs. 1.44
2	Corn meal;..... wheat middlings....	1456.5	147.13	816.77	58.33	11.35	9.09
3	Corn meal;..... linseed oil meal.....	1799.0	188.68	1098.50	52.50	6.09	4.62
4	Corn meal;..... soy beans.....	1729.0	189.27	1015.27	89.73	5.78	7.73
5	Corn meal;..... tankage.....	1786.0	189.20	1089.83	58.55	8.51	3.44
6	Corn meal;..... germ oil meal.....	1277.5	138.81	766.63	56.51	5.54	6.09
7	Corn meal.....	1306.5	90.54	867.12	36.19	3.07	1.45
8	Corn meal;..... wheat middlings....	1297.6	131.08	727.66	51.96	10.13	8.09
9	Corn meal;..... linseed oil meal.....	1338.7	139.88	814.38	38.91	4.52	3.42
10	Corn meal;..... soy beans.....	1327.5	145.32	779.51	68.89	4.44	5.93
11	Corn meal;..... tankage.....	1327.5	140.62	810.05	43.52	6.33	2.56
12	Corn meal;..... germ oil meal.....	1258.5	136.75	755.22	56.66	5.46	6.00

It is easily conceivable that the proteids of corn should not contain these primary nitrogenous groups of the kinds and in the proportions most useful for the building up of the proteids of the hog's body.

The rations of mixed origin furnish a greater variety of plant proteins, from which the animal can select constituents more exactly suited to its particular needs.

The wheat middlings ration was eaten in larger quantity than the two above mentioned, but the hogs consuming this feed did not eat heartily and were easily forced off feed.

Recent experiments indicate that the unfavorable effects of wheat bran and middlings, when used in too large proportion to other feeds, are due to the excessive amounts of magnesium which they contain.

Mineral salts exercise a regulative function over a great number of the vital processes in animals. The maintenance of this control requires that the various salts be present in the liquids of the body in definite quantitative relation, one to another. (See Bul. 201, Ohio Agr. Exp. Sta.).

Magnesium and calcium salts appear to be antagonistic in their action, and the introduction of excessive quantities of magnesium salts into the circulation seems to result in the withdrawal of calcium from certain tissues, to protect others from the action of magnesium. The excess of both is then excreted.*

Thus the consumption of feeds like bran and middlings, which are characterized by very high magnesium contents, may cause a considerable loss of calcium from the body.

The failure of certain investigators to maintain hogs on wheat middlings alone, may be due to this factor, as may also be the existence of "bran disease", "shorts disease", or "miller's horse rickets" in horses.

The author has made considerable use of wheat bran as a food for brood sows, and has regarded it very highly. The above facts regarding the effects of an excess of magnesium in the body recall to mind, however, a number of sows which broke down while on this ration. Some recovered when the pigs were taken away. Others had to be killed. The indications are that an excess of magnesium and the consequent loss of calcium from the body, together with the removal of salts through lactation, were responsible for these troubles. The use of chalk in the ration, with the bran, would certainly have tended to alleviate the unfavorable symptoms.

At the close of the experiment the hogs receiving linseed oil meal were cleaning up their feed much better than any others. They were consuming feed in excess of their ability to digest it, as was shown by the appearance of undigested meal in the feces, but their appetites never faltered.

The linseed, soy bean and tankage rations were each eaten practically to the full limit of the capacity of the hogs, so that the differences in palatability are not fully shown by the figures. The oil meal ration was consumed much more rapidly after the sixty days full-feeding than either the tankage or the soy bean rations.

The wheat middlings ration contained much the most phosphorus and lecithin. Corn is low in both, but corn and soy beans together, make a ration which is rich in these constituents.

*Mendel and Benedict: Journ. Biol. Chem., Vol. 4, No. 2; Amer. Journ. Physiol., Vol. 25, No. 1.
Malcom: Journ. Physiol., Vol. 32, p. 182.

Meltzer and Auer: Amer. Journ. Physiol., Vol. 14, p. 366; Vol. 21, p. 400.
Forbes: Bul. 207, Ohio Agr. Exp. Sta., pp. 34, 37, 39, 44, 47.

The tankage ration, with its high content of bone, was rich in phosphorus, but its lecithin content was low.

Lots 7-12, the limited ration series, were each to have been fed the same amount of digestible nutriment, but our plans did not work out with absolute exactness. The wheat middlings and germ oil meal lots were so capricious in their appetites that they had to be allowed the liberty of going their own gait, and they fell behind the standard.

The four other lots each received exactly the same number of pounds of digestible nutriment, but when the non-nitrogenous constituents were computed to "starch-equivalent", as in this table, the total amounts of nutriment no longer appear to be the same, because of the differences in the fat-content of the rations, fat having a higher value than starch.

As the final results stand, however, we have a basis for a very satisfactory comparison between the three most profitable rations fed, those containing linseed oil meal, soy beans, and tankage, on two levels as to quantity.

TABLE VI: GAIN IN WEIGHT PER POUND DIGESTIBLE PROTEIN
AND NON-NITROGENOUS STARCH-EQUIVALENT

Rations	Lot	Total nutriment consumed	Gain per pound nutriment	Lot	Total nutriment consumed	Gain per pound nutriment
		Lbs.	Lbs.		Lbs.	Lbs.
Corn.....	1	1033.3	.265	7	1044.5	.275
Corn; wheat middlings....	2	1103.9	.344	8	983.4	.374
Corn; linseed oil meal.....	3	1413.2	.356	9	1047.6	.364
Corn; soy beans.....	4	1419.9	.358	10	1090.2	.328
Corn; tankage.....	5	1419.6	.354	11	1055.2	.327
Corn; germ oil meal.....	6	1041.05	.306	12	1025.6	.314

In the full-fed series, Lots 1-6, the gain per pound of digestible nutriment was less with the corn lot than with any other; the corn and germ oil meal ration was also distinctly less efficient than the other mixed rations. The linseed oil meal, tankage, and soy bean rations were found to have almost exactly the same ability to cause gain in weight, while the wheat middlings ration was less efficient in this regard.

In the limited ration series, Lots 7-12, the rations of corn, and of corn and germ oil meal, proved again to be less efficient than the others. The higher relative efficiency of the wheat middlings, and linseed oil meal rations in this series, if these figures represent the actual facts, would lead us to the conclusion that they have a use-

fulness which is due to factors which are as yet obscure. It is possible that the high phosphorus content of the middlings ration was an advantage, and that its high fiber content helped to satisfy the pigs. During most of the experiment this lot was really fed *ad libitum*. The linseed oil meal, soy bean and tankage lots suffered from a constant affliction of appetite, which may have retarded their fattening.

Too close a comparison should not be drawn between the results in these two series, because the two rows of pens were not exactly alike, there being slightly more sunshine in the pens of the limited ration series. The corn straight, the wheat middlings, and the germ oil meal rations, which were really fed *ad libitum* in both series, were all slightly more efficient in the second one.

It is impossible to make a statement of the financial outcome of such a comparison of feeds, which will be at the same time useful and true. The reason is that market conditions are never the same at two different times, or in two different places. The relative prices of feeds today, in any given market, do not apply in any other market, and in all probability will never again recur.

We would suggest that the cost of pork made from these rations be calculated as follows, using such prices for feeds as prevail at the time and place of interest.

Suppose corn meal to cost 56 cents per bushel, linseed oil meal \$30.00 per ton, and tankage \$40.00 per ton; or corn 1 cent per pound, oil meal 1.5 cents per pound and tankage 2 cents per pound. (See Table VII, page 252.)

With Lot 1 it took 471.7 pounds of corn to make 100 pounds of pork. At 1 cent per pound this corn would cost \$4.72. With Lot 3, receiving corn meal and linseed oil meal, there were required to produce 100 pounds of pork, 357.6 pounds of feed, of which 17.79 percent or 63.62 pounds were oil meal, (cost $63.62 \times 1.5 = 95.4$ cents), and 82.21 percent, or 293.98 pounds were corn, (cost \$2.94). Adding these two costs, \$0.95 and \$2.94, we find that 100 pounds of pork cost \$3.89.

With Lot 5, receiving corn meal and tankage, there were required 355.8 pounds of feed to make 100 pounds of pork. Of this feed, 91.94 percent, or 327.12 pounds, were corn—cost \$3.27; while 8.06 percent, or 28.68 pounds, were tankage—cost \$0.57. Adding these costs of corn and tankage, $\$3.27 + .57 = \$3.84$, the cost of 100 pounds of pork with this ration

In considering the replacement values of the supplements, as set forth in the fourth, fifth and sixth columns of figures in Table VII, it is necessary to bear in mind the fact that pork is not

TABLE VII: FEED CONSUMED, GAINS IN WEIGHT, AND VALUATION OF SUPPLEMENTS

Lots	Rations	Grain per cwt. gain	Average daily gain		Average daily feed	Values per ton of supplements corresponding to values of corn			Average initial weight	Average final weight
			Lbs.	Lbs.		Corn \$.40 bu.	Corn \$.50 bu.	Corn \$.60 bu.		
Series A. Ad libitum										
1	Corn meal.....	471.7	.91		4.31				114.2	169.0
2	Corn meal, 18.25 percent; wheat middlings, 81.75 percent.....	383.3	1.27		4.85	\$19.92	\$22.40	\$26.87	117.4	193.4
3	Corn meal, 82.21 percent; linseed oil meal, 17.79 percent.....	357.6	1.68		6.00	37.98	47.47	56.90	119.8	220.2
4	Corn meal, 80.43 percent; soy beans, 19.57 percent.....	340.4	1.69		5.76	40.56	50.73	60.94	118.6	220.2
5	Corn meal, 91.94 percent; tankage, 8.06 percent.....	355.8	1.67		5.95	67.73	84.38	101.82	116.6	217.0
6	Corn meal, 60.64 percent; germ oil meal, 39.36 percent.....	401.1	1.06		4.26	19.90	24.84	29.90	120.1	183.8
Series B. Limited quantity										
7	Corn meal.....	454.5	.96		4.35				119.5	177.0
8	Corn meal, 18.25 percent; wheat middlings, 81.75 percent.....	352.6	1.23		4.32	\$19.76	\$24.70	\$29.63	121.0	194.6
9	Corn meal, 82.21 percent; linseed oil meal, 17.79 percent.....	350.1	1.27		4.44	40.20	50.42	60.38	120.0	196.2
10	Corn meal, 80.43 percent; soy beans, 19.57 percent.....	370.8	1.19		4.43	32.46	40.52	48.78	120.0	191.6
11	Corn meal, 91.94 percent; tankage, 8.06 percent.....	384.8	1.15		4.43	50.35	62.92	75.44	116.6	185.6
12	Corn meal, 60.64 percent; germ oil meal, 39.36 percent.....	390.5	1.07		4.16	21.02	26.28	31.48	120.6	185.0

necessarily made most cheaply by the use of the supplement having the highest replacement value, as was demonstrated by the author in Missouri Bulletin No. 65.

Consider, for instance, the above computation of the cost of pork. The cost is practically the same where linseed oil meal, and where tankage are used, even though tankage has a very much higher replacement value than linseed oil meal, as is shown in Table VII, on page 252. This is due to the higher cost of tankage, and the smaller percentage of tankage used to balance the ration.

Comparing corn alone with the supplemented rations, we find that the linseed, tankage, and soy bean rations made about 85 percent more gain in the same time. The longer the feed, the greater is the loss of possible profit by feeding corn by itself.

The wheat middlings rations were more efficient than corn alone, the gain being greater, and the feed required being less. It must be borne in mind, however, that the character of the increase was very different in these two cases. The middlings hogs grew, but did not fatten much. The corn-fed hogs were perceptibly smaller, but fatter. The middlings hogs had conspicuously heavy coats of hair.

The fourth, fifth and sixth columns of figures state the costs of the supplements at which it would be an even thing whether they be used with the corn or not. If the supplements can be purchased at prices less than those stated, they will return a profit; otherwise not.

As corn varies in price between 40 and 60 cents per bushel, wheat middlings may be valued between \$19.92 and \$26.87 per ton; that is, to make it an even thing whether the middlings be used with the corn, or the corn be fed alone.

In the same way linseed oil meal varies in value, in terms of corn saved by its use, between \$37.98 and \$50.90 per ton; soy beans between \$40.56 and \$60.94 per ton; tankage between \$67.73 and \$101.82 per ton, and germ oil meal between \$19.90 and \$29.90 per ton.

The linseed oil meal, soy bean and tankage rations returned very satisfactory profits, and each produced gains in weight of about 1.7 pounds per head, per day, at about the same expenditure of feed. These foodstuffs will still return a profit at considerably increased cost, as is indicated by the valuations in the fourth, fifth and sixth columns of figures.

The soy bean has the advantage of being capable of successful home production. This test shows it to be particularly valuable as a hog feed. The method of this experiment furnishes a very satis-

factory comparison between this feed and the others used, but for profit we would doubtless use another system. For fall feeding the beans may be "hogged off", corn being fed in addition, and the hogs being restricted as to range over the field, by a movable fence. For winter feeding the beans may be cut a little early, cured as hay, and fed as a supplement to corn, without preparation.

The germ oil meal lots were a disappointment. This corn product seems not to be the proper thing to use as a supplement to corn; other feeds are better adapted to this purpose. The ration was neither cheap, nor efficient, nor palatable, and the gains made were not large.

The linseed oil meal, soy bean, and tankage hogs were much fatter than the corn and middlings lots. The linseed oil meal hogs graded "prime" in condition, and possessed that uniformly high finish which has made this feed a favorite with breeders of fine stock. The soy bean and tankage lots were graded "choice", being not quite so fat nor so uniformly fat as the linseed lot. The germ oil meal lot graded "good," was fatter than either the corn or the middlings hogs, and ranked ahead of the corn lot, but much behind the middlings lot in apparent growth of frame.

From the limited ration series, Lots 7-12, we may draw this practical conclusion: The less gain a hog is making, the more nearly does corn become a perfect food, and the less will be the profit from the use of nitrogenous supplements. Large consumption of feed and large gains in weight are essential to the most profitable use of supplementary feeds. Corn is more rich in protein than is necessary in a mere maintenance ration, but the further we get from the maintenance ration, that is, the more flesh we produce in a given time, the less efficient is corn alone, and the greater is the need of supplements. This principle receives constant recognition from dairymen, who know that the more milk a cow produces, the narrower must be her ration, but we do not happen to have seen the point mentioned in connection with meat production. It is, of course, so obviously true as to need no proof.

After the completion of the feeding test, the sixty hogs were shipped to a small packing-house at Alton, Illinois, where arrangements had been made for the killing.

After the hogs were dressed, the carcasses were cooled, and the tenderloin muscles dissected out, weighed and placed in screw-top bottles with rubber rings to prevent evaporation.

A cross-section taking in the sixth rib was procured from each hog. Each cross-section, as cut out, was wrapped in parchment paper, to prevent evaporation, until it could be sampled for analysis.

TABLE VIII: AVERAGE SLAUGHTER WEIGHTS

Lot	Rations	Live weight		Gross dressed weight		Leaf-lard		Kidneys		Heads and jowls		Lungs		Heart		Liver		Spleen		Tenderloin muscles*		Percent dressed to live weight**
		Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Ozs.	Ozs.	Lbs.	Lbs.	Lbs.	Lbs.	Ozs.	Ozs.	Lbs.	Lbs.	Ozs.	Ozs.	Ozs.	Ozs.	
1	Corn.....	173.8		132.8		4.61		6.15		13.03		1.78		8.38		2.78		3.10		5.43		76.4
2	Corn; wheat middlings.....	186.0		146.0		3.92		8.60		13.70		2.63		10.03		3.74		3.83		7.63		74.5
3	Corn; linseed oil meal.....	225.6		175.1		5.85		8.65		15.94		2.40		10.83		3.83		4.05		7.10		77.6
4	Corn; soy beans.....	223.8		174.0		6.34		8.68		16.29		2.19		10.13		3.89		3.78		6.68		77.7
5	Corn; tankage.....	223.6		173.0		6.47		8.13		16.00		1.96		10.20		3.64		3.35		6.53		77.4
6	Corn; germ oil meal.....	190.2		143.7		4.84		7.03		13.39		2.39		9.00		3.24		3.25		6.44		75.6
7	Corn.....	183.2		141.2		6.48		6.95		13.06		1.61		8.20		2.94		2.53		4.78		77.1
8	Corn; wheat middlings.....	198.2		146.2		4.00		8.70		13.88		2.24		10.03		3.71		3.70		6.85		73.8
9	Corn; linseed oil meal.....	203.6		156.4		5.12		7.53		13.81		1.80		10.30		3.56		3.58		6.78		76.8
10	Corn; soy beans.....	196.0		152.6		5.07		8.78		14.54		2.16		10.18		3.76		3.35		6.08		77.8
11	Corn; tankage.....	194.4		150.5		4.82		7.13		14.44		1.64		9.70		3.40		3.02		6.15		77.4
12	Corn; germ oil meal.....	192.4		143.5		4.17		7.75		14.09		1.80		8.95		3.40		3.23		6.75		74.6
13	Check lot.....	120.6		87.5		2.29		5.21		6.75		1.13		7.25		2.46		2.78		4.61		72.6

* Weight of one muscle.

** At Columbia.

In preparing them for sampling, the skin and bones were removed, and the remainder repeatedly run through a sausage mill so that the parts might be well mixed. Composite samples were prepared from each lot of five pigs, and after much grinding and mixing were put into small bottles, packed in an ice-cream packer, and expressed to Columbia for analysis. The tenderloins were similarly treated.

As the carcasses were being cut up, each was examined by the superintendent of the packing plant. None were found objectionably soft. The linseed oil meal hogs were characterized by conspicuous thickness, firmness, and especially evenness, of the covering of fat. The butchers learned in a very few minutes to pick out those that had received oil meal, by their marked excellence. They were especially interested because it had been their belief that this feed produced soft pork.

The soy bean hogs were slightly less firm than the linseed oil meal hogs, but not objectionably so. The tankage hogs also occasioned favorable comment.

In general, those hogs which were least fat were least firm in the fat. This explains the fact that the middlings hogs were the softest, they being the least fat. A middlings-fed hog that is finished has an unexcelled, brittle hardness of fat.

The germ oil meal hogs were also too backward in condition to appear to especial advantage. The most noticeable thing about the cutting, however, was the relative development of fat and lean in the carcasses. Every hog which was conspicuous for the thickness of its lean meat came from a wheat middlings lot. The characteristic of the corn-fed hogs was that these appeared to have deposited much fat within the lean, but were not especially thick in either fat or lean.

The linseed oil meal, and soy bean hogs had the appearance of having both grown and fattened, neither function predominating to a noticeable extent.

These hogs, weighing about 120 pounds at the beginning of the experiment, were fed out in sixty days, the best of them to good fat-hog weights, as is seen in the first column of figures in Table VIII, page 255.

The last column gives the percentage of dressed to live-weight. The lack of proper scales at the packing house made it necessary that we base this figure on our Columbia weights, hence the hogs appear to have dressed a low percentage of carcass.

In the full-fed series, Lots 1 to 6, the linseed, soy bean and tankage lots outdressed the corn lot in spite of having heavier waste parts. They were decidedly fatter.

In the limited ration series, Lots 7 to 12, the soy bean and tank-age lots outdressed the corn lot, while in both series the wheat middlings lot ranked last as to percentage of dressed to live-weight. They had fattened very little and their offal parts were well developed.

These weights of parts are here set down to give them permanent record, but their true significance is not manifest in this form; the next three tables being so computed as to set forth their real usefulness.

In both series, (Table IX, page 258), the corn lots yielded the lowest percentage of net to gross dressed weight, while the middlings lots in each series yielded the highest percentage, followed in each case by the linseed oil meal lot. The net dressed weight is the gross dressed weight minus the head, leaf-lard and kidneys, and in some establishments, the ham facings. It represents the hog as sent to the cooler. If in the development of the hog, the head and the leaf-lard should fall behind the muscular system in rate of increase, we would have an increased percentage of net to gross dressed weight. This is just what took place in the middlings lots. Thickness of flesh, whether it be due either to development of fat or muscle, tends to increase the percentage of net to gross dressed weight. This is of importance to the packer, since the net dressed weight is worth more per pound than the gross dressed weight.

The percentage of leaf-lard is a good indication of the development of the internal fat generally. An abundance of internal fat in a hog is much in the packer's interest, but is not an advantage to a breeding animal on the farm. Pressure of internal fat upon reproductive and other vital organs cannot fail to operate disadvantageously, through impairment of the circulation of the blood in those parts.

The largest proportion of kidneys, lungs, heart, liver and spleen were in both series found in the wheat middlings lot. This is partially due to the fact that these hogs were not fat, but largely also to the fact that these parts were well developed, as will be apparent from an inspection of Table VIII, page 255. The lungs of the middlings lots, Nos. 2 and 8, were both relatively and absolutely larger than any others. The tenderloin muscles were also large, in Lot 2 being both relatively and absolutely larger than in any other lot, while in Lot 8 they were absolutely heavier than any other in the second series, but relatively not heavier than in the germ oil meal lot. The only difference known to exist between the middlings rations and those fed to the other lots, which might account for this remarkable showing, is in the phosphorus content, the middlings rations being especially rich in easily assimilable phosphorus compounds.

TABLE IX: RELATION OF DIFFERENT PARTS TO DRESSED CARCASS

Lot	Ration	Percent net to gross dressed weight	Percent leaf-lard	Percent kidneys	Percent head and jowl	Percent lungs	Percent heart	Percent liver	Percent spleen	Percent tenderloin
1	Corn.....	86.4	3.47	.290	9.81	1.34	.394	2.09	.146	.255
2	Corn; wheat middlings.....	87.6	2.69	.368	9.38	1.80	.430	2.56	.164	.327
3	Corn; linseed oil meal.....	87.2	3.34	.309	9.10	1.37	.387	2.19	.144	.254
4	Corn; soy beans.....	86.7	3.64	.312	9.36	1.26	.364	2.24	.136	.240
5	Corn; tankage.....	86.7	3.73	.294	9.24	1.13	.367	2.10	.121	.236
6	Corn; germ oil meal.....	87.0	3.43	.242	9.32	1.66	.381	2.25	.141	.280
7	Corn.....	85.9	4.59	.308	9.25	1.14	.363	2.08	.112	.211
8	Corn; wheat middlings.....	88.8	2.73	.372	9.49	1.53	.428	2.54	.158	.283
9	Corn; linseed oil meal.....	87.6	3.27	.301	8.83	1.15	.412	2.28	.143	.271
10	Corn; soy beans.....	86.8	3.32	.359	9.54	1.42	.417	2.46	.137	.249
11	Corn; tankage.....	86.9	3.13	.296	9.59	1.09	.403	2.26	.158	.255
12	Corn; germ oil meal.....	87.0	2.90	.338	9.82	1.25	.390	2.37	.125	.294
13	Check lot.....	89.3	2.62	.475	7.71	1.29	.516	2.81	.140	.329

It is interesting to note that in Lot 13, the check lot, which was killed at the beginning of the experiment, the percentages of kidneys, heart, liver, spleen and tenderloin muscle were all larger than in any of the other lots after sixty days' feeding. The lungs, however, in a number of cases were relatively heavier in the fattened hogs than in this check lot.

TABLE X: PERCENT OF INCREASE IN LIVE WEIGHT AND IN CERTAIN PARTS AND ORGANS

Lots	Rations	Live-weight	Leaf-lard	Kidneys	Lungs	Heart	Liver	Spleen	Tenderloins
1	Corn	52.2	112.4	24.74	66.4	22.16	19.31	17.87	24.31
2	Corn;wheat middl'gs.	67.0	75.8	69.62	139.1	42.07	56.49	41.32	70.31
3	Corn; linseed oil meal	88.3	156.6	66.99	114.3	50.42	56.97	46.73	55.02
4	Corn; soy beans.....	88.7	181.8	69.53	97.3	42.08	60.74	38.46	47.46
5	Corn; tankage.....	91.8	191.4	61.31	79.8	45.51	52.94	24.53	46.74
6	Corn; germ oil meal	58.4	112.3	35.45	111.5	24.65	32.24	17.32	40.30
7	Corn	53.3	185.5	34.69	43.8	14.21	20.49	-8.00	4.82
8	Corn; wheat midd'gs	63.8	74.0	66.35	98.2	37.96	50.20	32.61	48.26
9	Corn;linseed oil meal	69.7	124.0	45.37	60.7	42.86	45.30	29.24	48.03
10	Corn; soy beans.....	63.3	122.4	69.50	92.9	41.19	53.46	20.93	32.75
11	Corn; tankage.....	66.7	117.1	41.47	50.5	38.37	42.85	8.63	38.20
12	Corn; germ oil meal.	59.5	82.1	48.75	59.3	23.45	38.21	16.19	46.42

In the sixty days of this experiment these 120-pound hogs increased in weight to the extent of 52-92 percent, according to the amount and kind of feed. Corn alone produced the smallest percentage of increase. The rations containing linseed oil meal, soy beans and tankage, in the full-fed series, produced practically the same percentage of increase in weight. They received the same amount of nutriment, (Table VI, page 250), and hence gained with equal efficiency. This gives us an excellent opportunity to judge of the difference in the kind of gain produced by these rations. The gain in leaf-lard differed considerably, the tankage ration being first, the soy bean ration being second, and the linseed oil meal ration third. The gain in tenderloin muscles also differed, but here the order of these three lots was just reversed, the linseed ration seeming to produce the most growth, the soy bean ration next, and the tankage ration last. The tankage ration contained the most corn. These three lots gained in lungs and in spleen in the same relative order as in the tenderloin muscles; that is, linseed oil meal first, soy beans second, and tankage third.

The wheat middlings ration, No. 2, with much less gain in live weight, gained very much more than the linseed oil meal, soy bean or tankage rations, in weight of tenderloin muscle. This ration excels all others in this regard in both series. In the full-fed series the middlings lot excelled all others in the gain made in kidneys and lungs, as well as in the tenderloin muscles.

The germ oil meal lot, No. 6, would appear from the increase in the leaf-lard, not to have fattened much better than the corn lot, but the additional protein caused a markedly greater increase in kidneys, lungs, liver and tenderloin muscles in this germ oil meal lot than in the corn lot, No. 1.

The corn lot seems to have made the least increase of all in live weight, kidneys, lungs, heart, liver, and tenderloin muscles. These observations are true in both series.

In the second, or limited ration series, Nos. 7-12, the corn, and the germ oil meal rations produced the least gain in weight. In this series the best comparisons may be made between Lots 7, 9, 10 and 11, since they received very nearly the same amounts of nutriment, as is seen in Table VI, page 250.

The corn lot, No. 7 in this series, gained much more in leaf-lard than other lots. It was last of all, however, in increase of every other part observed.

The kidneys and livers of the soy bean lot excelled others in gain in weight, while in the middlings lot the lungs and tenderloin muscles were heavier than in other lots.

The data in this table have reference to the gain in each organ by itself, independent of all else. In the following table, No. XI, page 261, the gain in these organs is in each case referred to the gain in live weight, so that we are able to say that for each percent of gain in live-weight of the animal, each of these organs increased a certain part of one percent of its own weight. In case the animal were developing just symmetrically in all parts, the percent of gain in each one of these portions would be the same as in live-weight. The departures from this order are interesting and significant.

This table, more than any other, exhibits the real specific influence of these rations. In both series the corn lot gained in leaf-lard much more rapidly than in live-weight, and also gained relatively more in leaf-lard than any other lot. In all other parts except the lungs, the gain, relative to gain in weight of these corn fed hogs, is very low. It is probably more than a coincidence that the lungs and leaf-lard should exceed other parts in proportionate gain. These observations refer us to the two methods of disposal of the excess non-nitrogenous starch-equivalent which was present in the ration of

these corn-fed hogs. They must lay it onto the body as fat, or work it off through the lungs as carbon-dioxide. These hogs in close confinement seem to have disposed of it largely by making it into fat; in fact, nearly all of these hogs, ten out of the twelve lots, gained in leaf-lard more rapidly than in live-weight or in any other part observed. In the two middlings lots, and in these alone, the relative gain in lungs was greater than in leaf-lard. In no one of the twelve lots is the gain in any other part observed as great in relation to gain in live-weight as in leaf-lard and lungs.

TABLE XI: INCREASE IN WEIGHT OF VARIOUS PARTS AND ORGANS IN RELATION TO GAIN IN LIVE WEIGHT

Lots	Rations	Leaf-lard	Kidneys	Lungs	Heart	Liver	Spleen	Tenderloin
1	Corn.....	2.15	.47	1.27	.425	.370	.342	.47
2	Corn; wheat middlings.....	1.13	1.04	2.08	.628	.843	.617	1.05
3	Corn; linseed oil meal.....	1.77	.76	1.29	.571	.645	.529	.62
4	Corn; soy beans.....	2.05	.78	1.10	.474	.685	.434	.54
5	Corn; tankage.....	2.08	.69	.87	.495	.577	.267	.51
6	Corn; germ oil meal.....	1.92	.61	1.91	.422	.552	.296	.69
7	Corn;	3.48	.65	.82	.267	.384	-.150	.09
8	Corn; wheat middlings....	1.16	1.04	1.54	.600	.787	.511	.76
9	Corn; linseed oil meal.....	1.78	.65	.87	.615	.650	.420	.69
10	Corn; soy beans.....	1.93	1.10	1.47	.651	.845	.331	.52
11	Corn; tankage.....	1.75	.62	.76	.575	.642	.129	.57
12	Corn; germ oil meal.....	1.38	.82	1.00	.394	.642	.272	.78

In each one of the twelve lots it is true that the relative gain of the spleen is less than that of any other part observed. Its function in the body seems to be fulfilled without so much increase in weight as occurs in these other organs.

The wheat middlings lots developed kidneys, lungs and tenderloin muscles to a greater extent than other parts.

In both series the corn, tankage and germ oil meal rations produced much smaller relative gains in weight of spleen than did other rations. These three rations are the ones made up most largely of corn.

TABLE XII: RELATION OF GROWTH TO INCREASED WEIGHT OF LEAF-LARD

Lot	Rations	Leaf-lard	Lungs	Spleen	Kidneys	Heart	Liver	Tenderloin	Phosphorus Lbs.
2	Corn; middlings.....	1.13	2.08	.617	1.04	.628	.843	1.05	11.35
3	Corn; linseed oil meal.....	1.77	1.29	.529	.76	.571	.645	.62	6.09
4	Corn; soy beans.....	2.05	1.10	.434	.78	.474	.685	.54	5.78
5	Corn; tankage.....	2.08	.87	.267	.69	.495	.577	.51	8.51
1	Corn.....	2.15	1.27	.342	.47	.425	.370	.47	3.04

Arranging as above, Lots 1 and 5, from Table XI, page 261 we place them almost in order of relative gain in weight of tenderloin muscles, liver, heart, kidneys, spleen, lungs and the amount of phosphorus in the rations, and inversely as the relative gain in leaf-lard. In so doing we display the relative tendencies of these rations to cause growth and fattening. The observations made on the germ oil meal lot do not conform so closely to this order.

We beg to repeat, however, that these characteristics are not of the supplementary foodstuffs, but of the rations. It is of importance that this distinction be noted. The relative efficiency would certainly have been very different if these rations had been made up of the same foodstuffs in other proportions. It is a fair comparison, however, in the sense that these rations were as nearly as we could get them of the same proportionate content of digestible protein and non-nitrogenous starch-equivalent.

The tankage ration does not cause growth to an extent proportional to its phosphorus content, because its phosphorus is so largely in the shape of bone, the inorganic phosphorus of which appears to be limited as to usefulness.

In the second series the same tendencies are manifest, but the agreement is less orderly. These results are at best hardly more than suggestive since the method of work was necessarily crude under the conditions existing.

TABLE XIII: RELATION OF PHOSPHORUS TO DEVELOPMENT OF MUSCLE

Lot	Rations	Total phosphorus consumed	Total gain in weight of lot	Gain in weight of muscle of lot	Total lecithin consumed	Fat in muscle
		Grams	Lbs.	Percent	Grams	Percent
2	Corn; wheat middlings.....	5149.3	380	70.2	4123.2	5.04
5	Corn; tankage.....	3862.4	502	46.6	1560.4	5.17
3	Corn; linseed oil meal.....	2762.9	503	56.1	2095.6	4.01
4	Corn; soy beans.....	2624.1	508	47.3	3506.3	4.79
6	Corn; germ oil meal.....	2512.5	318.5	40.3	2762.4	4.67
1	Corn.....	1377.6	274	24.4	653.2	7.28
8	Corn; wheat middlings.....	4587.3	368	48.3	3669.6	4.54
11	Corn; tankage.....	2870.8	345	38.2	1161.2	3.92
12	Corn; germ oil meal.....	2475.3	322	46.4	2721.6	4.31
9	Corn; linseed oil meal.....	2048.5	381	47.9	1551.3	5.57
10	Corn; soy beans.....	2015.8	358	32.6	2689.8	3.21
7	Corn.....	1392.6	287.5	4.7	657.7	8.29

This table shows both series arranged according to the phosphorus content of the total feed administered. There is no apparent connection between the phosphorus content of these rations and the gain in live-weight; nor between the phosphorus content and the percent of fat in the muscle; neither does the lecithin content of the ration seem to be closely in accord with these other items noted, but the phosphorus content in each series does correspond somewhat definitely with the gain in the weight of the tenderloin muscles, especially when we consider the fact that as previously observed, tankage carries its phosphorus mostly as bone. It is not impossible that the significant connection between the gain in muscles and the composition of the ration, should be between these organs and some other constituent or characteristic of the ration, which varies directly as the phosphorus. The probability, of course, is that this is an essential connection; that the phosphorus is used as a nutrient, and that at least those rations containing less phosphorus than the middlings rations do not contain as much of this element as is necessary to maximum muscular growth.

TABLE XIV: ANALYSIS OF TENDERLOIN MUSCLES

Lot	Rations	Water	Protein	Fat	Ash	Water in fat-free meat	Fat in water- free meat	Ash in fat- and water-free meat
		Percent	Percent	Percent	Percent	Percent	Percent	Percent
1	Corn.....	71.55	19.187	7.28	1.1076	77.38	25.77	5.282
2	Corn; wheat middlings	72.94	20.675	5.04	1.1505	76.81	18.62	5.225
3	Corn; linseed oil meal..	74.08	20.506	4.01	1.1790	77.17	15.47	5.381
4	Corn; soy beans.....	72.91	20.944	4.79	1.1228	76.58	17.68	5.035
5	Corn; tankage.....	73.66	19.783	5.17	1.1280	77.68	19.63	5.328
6	Corn; germ oil meal...	73.53	20.549	4.67	1.0760	77.13	17.64	4.936
7	Corn.....	71.52	19.033	8.29	1.0630	77.98	29.05	5.265
8	Corn; wheat middlings	73.58	20.581	4.54	1.1040	77.08	17.18	5.046
9	Corn; linseed oil meal..	72.56	20.456	5.57	1.1750	76.84	20.29	5.373
10	Corn; soy beans.....	74.14	21.224	3.21	1.1320	76.60	12.41	4.998
11	Corn; tankage.....	73.93	20.593	3.92	1.1070	76.95	15.03	4.998
12	Corn; germ oil meal...	74.17	20.196	4.31	1.0540	77.51	16.69	4.898
13	Check lot.....	73.53	19.926	4.61	1.1041	77.81	17.42	5.051

In both series the muscles of the germ oil meal lots have less ash, and the muscles of the linseed oil meal lots have more ash than is found in any other lots. These observations are true when the percentage of ash is computed, either on the basis of the meat as a whole, or on the fat- and water-free meat.

It is also worthy of note that in both series the corn lot ranks ahead of the middlings, soy bean, and germ oil meal lots as regards the percentage of ash in the fat- and water-free meat, though on the basis of the meat as a whole, the ash is low in the corn lots, because of the high percent of fat.

The percent of fat in the water-free meat shows the corn lot to have had much the fattest muscles; that is, more fat was deposited within the muscles than in other lots. This is of importance as indicating the quality of the flesh from a culinary standpoint, an intimate intermingling of fat and lean being considered essential to the highest quality.

The lower percentages of fat and the higher percentages of water were usually found associated. This would be expected on arithmetical grounds. When we compute the percentage of water in the fat-free meat, however, factors other than arithmetical ones seem to be operative. The percentage of water in the fat-free meat of the corn lots was high in both series.

The tendencies of corn to deposit fat within the muscles, and to restrict the development of the nitrogenous tissues, as is proven by the small muscles of the corn-fed hogs, are probably due to the fact that corn furnishes to the muscles more carbohydrate food than they have occasion to oxidize in the production of energy, it being, therefore, of necessity, deposited as fat; and further, to the fact that corn is probably lacking in the amount both of protein and phosphorus requisite to maximum muscular growth of a normal composition.

During this experiment these hogs, except in the corn lots, were receiving much narrower and more nearly normal rations than the one on which they had been raised. They were really corn-fed when the experiment began. It is interesting to note in comparing the check lot with some others that were fed for sixty days, that the change in feed, together with the increase in age, reduced the percentage of water in the fat-free meat even where it also reduced the percentage of fat in the meat.

The linseed oil meal ration, in the full-fed series, produced muscles that contained more water and ash, and less fat, than was found in any other lot. The fact of this low fat- and high water-content is difficult to explain. It seems not to have been due to fault in this sample, because the water in the fat-free meat of the cross-sections in the same series was also high; but in the limited ration series the oil meal lots, both with the muscles and the cross-sections, were characterized by a high fat content, and low percentage of moisture in the fat-free meat. The high proportion of ash to protein, however, holds in both samples of meat and both series, and so may be considered as characteristic of this ration.

TABLE XV: ANALYSIS OF THE MEAT OF THE CROSS-SECTIONS OF THE CARCASS.

Lots	Rations	Water	Protein	Fat	Ash	Water in fat-free meat	Fat in water- free meat	Ash in fat- and water-free meat
		Percent	Percent	Percent	Percent	Percent	Percent	Percent
1	Corn	32.13	7.944	59.53	.422	79.39	87.71	5.060
2	Corn; wheat middlings	36.44	8.940	53.33	.460	78.08	83.90	4.497
3	Corn; linseed oil meal .	28.48	7.459	63.72	.391	78.50	89.09	5.013
4	Corn; soy beans.....	28.19	7.754	63.36	.407	76.94	88.23	4.817
5	Corn; tankage.....	29.55	7.635	62.75	.341	77.25	89.07	4.429
6	Corn; germ oil meal...	33.81	9.050	56.99	.395	78.61	86.10	4.350
7	Corn	28.51	7.010	63.94	.375	79.06	89.44	4.967
8	Corn; wheat middlings	32.95	8.623	57.77	.463	78.02	86.16	4.989
9	Corn; linseed oil meal..	29.77	7.947	61.97	.418	76.27	88.24	5.061
10	Corn; soy beans.....	36.90	9.644	52.66	.496	77.94	83.45	4.751
11	Corn; tankage.....	33.40	8.862	56.92	.454	77.53	85.47	4.690
12	Corn; germ oil meal..	34.76	9.307	55.05	.538	77.33	84.38	5.280
13	Check lot.....	43.55	11.929	42.80	.726	77.13	75.82	5.322

In the sampling of the meat of the cross-sections, difficulties were encountered which were not satisfactorily overcome, and on this account these figures do not represent the facts with reference to the carcasses, with quite the definiteness that was desired.

The percent of fat in these cross-sections is due very largely to the subcutaneous deposit. The corn lots do not excel others in this matter to the same extent as in the percent of fat laid down within the muscles. In both series the linseed oil meal lots rank either first or second as to percent of fat, either on the basis of the whole meat, or on the basis of the water-free meat.

The relative percentages of protein and fat, show that this was exceedingly fat meat, even though these hogs would have been called only about two-thirds fattened. The fat in the water-free meat varies between 75.82 percent in the "thin" shot of the check lot and nearly 90 percent in several others.

The percentage of water in the fat-free meat of the corn lots, Nos. 1 and 7, was as in the tenderloins, very high; in these cross-sections it being decidedly higher than in other lots in both series, and hence reinforcing our previous observations in regard to this being a specific influence of the corn. Some other lots were fatter, and still others were not so fat, but in none of them was there so much water in the fat-free meat.

CONCLUSIONS FROM EXPERIMENT I.

In a comparison of corn alone, with corn supplemented by wheat middlings, linseed oil meal, soy beans, tankage and germ oil meal for full-feeding growing and fattening hogs,—all rations except the corn having the same nutritive ratio, namely 1:6.5,—as corn varied in cost between 40 and 60 cents per bushel, wheat middlings varied in value between \$20 and \$27 per ton, linseed oil meal between \$38 and \$57 per ton; soy beans between \$41 and \$61 per ton; tankage between \$68 and \$102 per ton, and germ oil meal between \$20 and \$30 per ton. (Table VII, p. 252.)

To yield a profit these supplements would have to be bought at prices lower than these valuations. The relative profits in the use of these supplements depends not only on the above "replacement values", but we must also consider the relative proportion of each in the balanced ration.

The six rations ranked as to palatability in the order in which the supplements are named:

- | | |
|------------------------|-----------------------|
| 1st. Linseed oil meal. | 4th. Wheat middlings. |
| 2nd. Digester tankage. | 5th. Germ oil meal. |
| 3rd. Soy beans. | 6th. Corn alone. |

Where hogs were full-fed on these rations, the middlings ration was 23 percent more efficient than corn alone, the linseed oil meal ration 32 percent, the soy bean ration 38.5 percent, the tankage ration 32.6 percent, and the germ oil meal ration 17.6 percent more efficient to cause gain in weight. (Table VI, page 250.)

Where these six rations were fed in practically equal but somewhat restricted amounts, the middlings ration was 28.9 percent more efficient than corn alone, the linseed oil meal ration 29.8 percent, the soy bean ration 22.6 percent, the tankage ration 18.1 percent, and the germ oil meal ration 16.4 percent more efficient than corn by itself.

The soy bean, tankage, and linseed oil meal rations produced equal gain in weight from the same expenditure of digestible nutriment; the wheat middlings, germ oil meal, and straight corn rations were much less efficient.

Linseed oil meal, tankage, and soy beans were both very efficient and very palatable as supplements to corn; middlings was efficient in the production of increased weight, but was much less palatable, while germ oil meal was neither efficient nor palatable, as compared with the other supplements.

The character of the increase produced by these rations was quite different. The tendency of five of these rations to cause growth of muscle and of internal organs was in the following order; wheat middlings, linseed oil meal, soy beans, tankage and corn alone. This was practically in accord with the phosphorus content of the rations; the tankage ration, however, failed to make growth in accord with its phosphorus content, probably because of the fact that its phosphorus was present mostly as bone. (Tables XI, XII, and XIII, pages 261 and 262.)

The tendency of these rations to fatten, as evidenced by the increase in the leaf-lard, was in the reverse order from that indicating tendency to cause growth.

The probability is that corn does not contain as much phosphorus as is necessary to the *maximum* muscular growth of which the animal is capable.

Corn alone caused a deposition of much more fat within the muscles, that is, between the fibers, than any other ration. (Table XIV, page 263.)

The tenderloin muscles of the corn-fed hogs contained less water than muscles from any other lot, but the percentage of water in the fat-free muscles of these corn-fed hogs was higher than in any other lot in the limited ration series, and exceeded only by the tankage lot in the full-fed series. The tankage ration was 92 percent corn.

In the meat of the cross-sections of the carcasses, the fat-free meat of the corn-fed hogs, in both series, contained decidedly more water than did any other lot, though the percentage of water in the meat as a whole was very low. (Table XV, page 265.)

The tenderloin muscles of the corn-fed hogs, in both series, were lower in protein than the muscles of any other lot. In the cross-sections the protein was also low.

The ash in the tenderloin muscles and cross-sections of the corn-fed hogs, in both series, was higher in the fat- and water-free meat than it was in the meat from the middlings, soy beans, and germ oil meal lots; and in two cases out of the four, was higher than in the tankage lots.

When compared with these more highly nitrogenous rations, corn by itself seems to produce smaller muscles which are peculiarly rich in fat; the moisture content of the meat as a whole is low, but the moisture in the fat-free meat is very high; the protein itself is low in amount, but the proportion of ash to protein is rather high.

The most striking peculiarity of the linseed oil meal ration is the high proportion of ash to protein in the meat produced by this feed.

TABLE XVI: PERCENTAGE COMPOSITION OF FOODSTUFFS USED IN
EXPERIMENTS II AND III.

	Water	Nitrogen-free extract	Protein	Ether extract	Crude fiber	Ash	Calcium	Mag- nesium	Potas- sium	Sodium	Sulphur	Phos- phorus	Chlor- ine
Coru.....	16.68	67.76	8.67	4.10	1.65	1.36	.009	.110	.280	.046	.141	.295	.040
Hominy.....	15.97	75.01	7.61	.86	.23	.36	.004	.018	.096	.011	.121	.049	.048
Blood flour.....	11.44	.....	82.50	1.00	.....	3.04	.390	.068	.096	.370	.656	.210	.280
Bone meal.....	.....	.....	24.59	.....	.....	63.31	24.120	.530	.076	.548	.100	11.390	.041
Bran extract	92.58	4.95	1.40	.....	....	1.20	.018	.148	.253	.026	.037	.261	.004

The germ oil meal ration occupied the opposite extreme from the linseed oil meal as regards the ash content of the tenderloin muscles, the percentage being lower than with any other lots.

In a number of lots there was less fat in the tenderloin muscles of the hogs which were fed for sixty days than there was in the muscles of the check lot, which was killed when the experiment began, and also in several lots there was an apparent loss of ash from the fat- and water-free meat during fattening. These facts are due to the hogs' being essentially corn-fed at the time the experiment began.

The increase in live-weight of the corn-fed hogs was more largely internal fat, and less largely muscles, than in any of the hogs which received higher-proteid ration. The hogs which received wheat middlings occupied the opposite extreme in this matter; their increased weight was more largely muscle, and less largely internal fat, than in any other lot. This comparison has an important bearing on the feeding of breeding animals, on whose reproductive efficiency excessive development of internal fat has an injurious effect, probably through restriction of circulation in the sexual organs, by the mechanical pressure of surrounding fat. (Table XI, page 261).

EXPERIMENTS II AND III

The general method of work was the same as in Experiment I. As in this series, five hogs were fed in each lot, one lot was killed at the beginning of each experiment, to serve as a basis for judgement as to changes produced by the experimental feeding, and a second lot was fed on corn alone, as a further basis for comparison.

The rations fed in these experiments were as follows:

EXPERIMENT II

- Lot 1 Corn.
- " 2 Hominy, blood-flour, bran-extract, (larger amount).
- " 3 Hominy, blood-flour, lecithin.
- " 4 Hominy, blood-flour, bran-extract, (smaller amount).
- " 5 Hominy, blood-flour, bone-meal.
- " 6 Hominy, blood-flour, sodium phosphate.
- " 7 Check lot, killed at beginning of experiment.

EXPERIMENT III

- Lot 1 Corn.
- " 2 Check lot, killed at beginning of experiment.
- " 3 Hominy, blood-flour, bran-extract.
- " 4 Hominy, blood-flour, bone-meal.
- " 5 Hominy, blood-flour.

TABLE XVII: DIGESTION COEFFICIENTS OF THE FOODSTUFFS
USED IN EXPERIMENTS II AND III

	Protein	Nitrogen- free extract	Crude fiber	Ether extract
	Percent	Percent	Percent	Percent
Corn.....	86	95	40	76
Hominy	86	95	40	76
Blood flour	62	....	..	100
Bran extract.....	76.2	86.2	..	...

TABLE XVIII: DIGESTIBLE NUTRIENTS PER HUNDREDWEIGHT OF
FOODSTUFFS USED IN EXPERIMENTS II AND III

	Protein	Carbohy- drates	Ether extract
	Pounds	Pounds	Pounds
Corn	7.456	65.032	3.116
Hominy.....	6.545	71.352	.654
Blood flour	51.150	.....	1.00
Bran extract.....	1.067	4.267	.....

The digestion coefficients are, as in Experiment I, largely assumed, but the same basal ration was fed in each case, and hence if there is error in these coefficients it is the same in each lot, and does not affect comparisons.

The hominy is assumed to have the same digestion coefficients as the whole corn.

The blood-flour has been assigned the same coefficients as reported by Dietrich and König, (Composition and Digestibility of Cattle Foods, Vol. II).

The bran-extract is assigned the same coefficients as wheat middlings, as determined by Snyder of Minnesota.

In Experiments II and III we have considered the balance between the inorganic acids and bases in the rations fed. This appears to be a matter of much importance, at least as fundamental a one as the balance between proteids and non-proteid organic nutrients, the so-called nutritive ratio. (Table XIX, pages 271 and 272.)

The significance of this factor of mineral base and acid balance is discussed by the author in Ohio Bul. 207. Very briefly the facts are as follows: There are constantly being formed in the animal body, from the foods and from the tissues, inorganic acids which must be neutralized in order that the neutrality of the liquids and

TABLE XIX: AVERAGE DAILY NUTRIENTS PER HEAD, EXPERIMENT II.

Lot	Rations Grams	Digest- ible protein Grams	Digestible starch equivalent* Grams	Nutritive ratio	Calcium Grams	Magnes- ium Grams	Potas- sium Grams	Sodium Grams	Sulphur Grams	Phos- phorus Grams	Chlorine Grams	Excess normal acid C. C.
1	Corn..... 2114.2	157.6	1532.7	1 : 9.73	.199	2.326	5.920	.973	2.981	6.237	.846	217.90
2	Hominy..... 1991.8 Blood-flour..... 163.6 Bran extract, (larger amt.) 2039.4	236.7	1543.1	1 : 6.52	1.092	3.500	7.239	1.358	4.236	6.641	1.491	149.11
3	Hominy..... 2068.9 Blood-flour..... 187.3 Lecithin..... 4.00	231.2	1512.8	1 : 6.54	.822	.504	2.166	.921	3.728	1.562	1.518	198.50
4	Hominy..... 2074.3 Blood-flour..... 181.4 Bran-extract, (smaller amt.) 779.3	236.8	1550.4	1 : 6.55	.936	1.675	4.140	1.100	3.980	3.429	1.531	176.50
5	Hominy..... 1821.2 Blood-flour..... 162.4 Bone-meal..... 20.9	202.3	1331.8	1 : 6.58	5.747	.552	1.920	.915	3.286	3.610	1.337	54.91
6	Hominy..... 2068.4 Blood-flour..... 187.3 Sodium phosphate..... 1.8	231.2	1512.8	1 : 6.54	.822	.504	2.166	1.152	3.728	1.562	1.518	188.48

* Nitrogen-free extract and ether extract.

TABLE XIX: AVERAGE DAILY NUTRIENTS PER HEAD. EXPERIMENT III. Concluded.

Lot	Rations Grams	Digest- ible protein Grams	Digestible starch equivalent* Grams	Nutritive ratio	Calcium Grams	Magne- sium Grams	Potas- sium Grams	Sodium Grams	Sulphur Grams	Phos- phorus Grams	Chlorine Grams	Excess normal acid C. C.
1	Corn.....	1426.9	846.4	1 : 9.73	.134	1.571	3.998	.657	2.013	4.212	.571	147.14
3	Hominy.....	1548.6	1158.5	1 : 5.92	.842	1.272	3.144	.958	3.214	2.655	1.245	138.63
	Blood-flour.....	171.9										
	Bran-extract.....	589.7										
4	Hominy.....	1570.4	1149.4	1 : 5.98	3.406	.463	1.684	.879	3.054	2.390	1.247	90.86
	Blood-flour.....	171.6										
	Bone-flour.....	11.0										
5	Hominy.....	1286.9	945.1	1 : 5.98	.616	.332	1.378	.672	2.500	0.934	1.021	122.70
	Blood-flour.....	143.3										

* Nitrogen-free extract and ether extract.

tissues may be maintained and the continuance of life thus rendered possible. The basic minerals in foods contribute to one side of this account, and the acid minerals to the other. An amount of acid mineral elements in the food in excess of the animal's capacity to neutralize them in normal ways may cause a withdrawal of basic minerals from the body, and, in consequence, most serious disturbances of nutrition.

The basic mineral elements considered in this connection are calcium, magnesium, potassium, and sodium; the acid minerals, sulphur, phosphorus, and chlorine.

In determining this balance between basic and acid minerals, we compute each to cubic centimeters of normal solution; that is, so that one cubic centimeter of any base will exactly neutralize one cubic centimeter of solution of any of the acid elements. Phosphoric acid is considered to be neutralized when two of its hydrogen atoms are replaced.

A peculiar relationship between the actions of calcium and magnesium in the body requires that a definite proportion between the quantities present in its liquids be maintained. They appear to be antagonistic, and an excess of magnesium occasions the liberation of calcium in quantity sufficient to counteract the effects of this excess of magnesium. The excess of both is then excreted. Thus an excess of magnesium, in proportion to calcium, may cause, just as may acid mineral elements, a withdrawal of calcium from the body, and pathological consequences such as usually result only from an excess of acids.

In Experiments II and III the rations are all characterized by an excess of mineral acid over mineral base.

The only differences of moment in this regard among the rations are in the somewhat lower excess of acid in the bone meal lot than in others, and the considerably greater excess of acid in corn than in the mixed rations. The corn ration besides having the most acid ash, has the least calcium, sodium, chlorine and sulphur, and the most magnesium, potassium and phosphorus, and the smallest proportion of proteid to non-proteid organic nutrients.

Experiment II. The hogs used in this experiment weighed about 125 pounds each; were mostly grade Poland Chinas of common quality; were six months old, in stock condition, and had been raised on corn and grass. The preliminary feeding occupied two weeks' time. The experiment was conducted during April and May of 1906.

In this test we sought to learn how a lack of phosphorus affects (1) the development of swine, and (2) the composition of their tissues; and (3) to compare bone meal, water extract of wheat bran, sodium

phosphate and lecithin as sources of phosphorus for growing pigs. In this experiment we consider the nutritive values of two organic phosphorus compounds, phytin, the principal phosphorus compound in the bran-extract, and lecithin; and two inorganic compounds, sodium phosphate, and calcium phosphate, as found in bone meal.

The distinction between organic and inorganic phosphorus compounds is largely arbitrary, and not always satisfactory, since inorganic salts of phosphoric acid, may enter into combination with organic compounds, and thus become organic phosphorus, without the agency of any vital process. Hence this distinction is not clean-cut and consistent. There is, however, a general dissimilarity between organic and inorganic phosphorus compounds, using the terms in the usual signification, and also a marked distinction in the nutritive values of these two groups. The usefulness of the distinction appears to outweigh its inaccuracies.

As a standard basal ration we adopted pearl hominy and blood-flour, which contained 82.5 percent of protein and only two-tenths of one percent of phosphorus. The hominy consists of the corn kernel minus the bran, or skin, and the germ, and is very much lower than corn in fat, fiber and ash constituents. These feeds furnished us a cheap and palatable balanced ration which was very low in phosphorus, and constituted a satisfactory basal ration for our comparisons. In subsequent work we have used blood albumen and wheat gluten as proteid supplements. They contain still less phosphorus than does blood flour.

In this experiment Lot 1 received corn alone; Lots 2 and 4 received different amounts of water-extract of wheat bran with their basal ration of hominy and blood-flour. This extract was prepared by soaking bran in luke-warm water, from one feeding period until the next, the hogs being fed twice daily. Two quarts of water were used in soaking each pound of bran. At feeding time the mash was put into a sack of thick cloth, and a cider press was found to be a quick and easy means of expressing the liquid. The feed, which in all lots was fed finely ground, was made into a moderately thick slop, either with the bran extract or with water. The extract was analyzed, and a correction was made in the basal ration for the two lots receiving it, so that the nutritive ratio might be the same in all cases, except with the corn lot. This bran extract was exceedingly rich in magnesium, potassium and phosphorus. The phosphorus was present mostly as phytin, a salt formed by the union of calcium, magnesium and potassium with phytic acid, a complex, organic, phosphoric acid which constitutes a large proportion of the phosphorus compounds of seeds. Where bacterial fermentation was considerable

during the preparation of the extract, the magnesium and phosphorus contents were more than twice as great as when sterile utensils and water were used, but in both cases the relation of total mineral bases to mineral acids was practically the same. The extract was in this regard about neutral.

Lot 3 consisted of but a single hog, the cost of lecithin making it impracticable to feed more. Four grams per day were fed to this hog, the lecithin being provided by Dr. W. Koch, of the Department of Physiology. The material was emulsified in water and added to the hominy and blood-flour. When it is considered that this lecithin contained but 3.883 percent of phosphorus it is apparent that the total amount fed did not provide any considerable quantity of this element. It was used with the hope of learning of its function in nutrition. It is a universal cell constituent of plants and animals, but does not constitute a large proportion of the total phosphorus of foods.

Lot 6 received with its basal ration just enough di-sodium phosphate to furnish to each pig the same amount of phosphorus as was received in lecithin by the pig in Lot 3. We refer to Lot 6 as the "low-phosphorus" lot.

In Lot 5, raw bone-meal was fed mixed with the ration. The bone-meal contained nitrogen equivalent to 24.59 percent of protein, but as this was doubtless present mostly as collagen, a substance of low food value, and the total amount of bone fed was only 13 pounds, no account of this protein was taken in the compounding of the rations. The phosphorus of this foodstuff was present mostly as tri-calcium phosphate.

Salt was given apart from the feed in each lot.

This experiment lasted 56 days.

It was hoped that all of the lots might be kept together in the amount of feed consumed but the rations were peculiar and it was soon apparent that each one would have to be fed with reference alone to the pigs consuming it.

With Lot 2 we attempted to find the amount of bran-extract that could be fed. It seems to be easy to overfeed with it, the pigs being willing to take much more of it than is beneficial to them. These pigs would cease eating before having cleaned up the feed well; appeared uneasy, coughed, gritted the teeth and allowed much saliva to drip from the mouth. Their joints became sore and swollen, and they moved around with reluctance and difficulty. These symptoms and other evidences of discomfort largely disappeared after the amount of bran-extract was cut down.

Lot 4, receiving less bran-extract, ate heartily and consistently at all times, and we must base our conclusions as to the effects of bran-extract as a food on the record of this lot. The amount of bran-extract fed to this lot was regarded as very satisfactory. The average amount fed was one pound to 2.89 pounds of dry feed. Probably a much greater amount could have been fed had we used chalk with the bran-extract to protect the pigs from the effects of the excessive amount of magnesium present.

The bone-meal lot was hard to feed. These hogs frequently went off feed, apparently because of the bone-meal, and on this account the total amount of feed eaten was smaller than in any other lot. We succeeded much better in feeding this bone-meal after grinding it to a fine flour in a pebble mill. This, however, had to be learned by experience.

The lecithin pig, Lot 3, was always ravenous for his feed and his ration was clearly more palatable than any other used in the experiment.

The other low-phosphorus lot, No. 6, also ate well. These two lots, Nos. 3 and 6, and No. 4, which received the smaller amount of bran-extract, were never fed up to their full capacity.

Lot 1, which received corn alone, ate consistently throughout the experiment; doing very well indeed for pigs so fed. Their record was unusually creditable to corn alone as a hog feed. This is, of course, largely due to the shortness of the experiment. They were fed as much as they would eat but did not consume as much feed as the other lots which were not fed to the limit of their appetites.

These rations affected the digestive system very differently. The corn ration was much the most laxative in its action. The ration of hominy and blood-flour was very constipating, most so in Lots 3 and 6, receiving lecithin and sodium phosphate, respectively, and least so in Lots 2 and 4, receiving bran-extract. The bone-meal lot was usually constipated, but sometimes scoured. This lot had rough coats, and did not shed off well. They did not like bone-meal fed mixed with the feed. The constipating character of the basal ration is doubtless due to its low contents of fibrous material and mineral matter.

Experiment III, conducted during October, November and December, 1906, was a repetition of Experiment II, except that the lecithin lot, and the lot receiving the larger amount of bran-extract were omitted, and no sodium phosphate was fed to the low-phosphorus lot.

The facts that the bone-meal lot in Experiment II was not in entirely normal state of nutrition, and did not make as large gains in weight as those lots with which we wished to compare it, rendered

close comparisons of results a little doubtful. Hence it seemed desirable to repeat this work. In Experiment III, as will be seen by Table XIX, page 272, the bone-flour lot, No. 4, ate more feed than the low-phosphorus lot, No. 5, and practically as much as the bran-extract lot. This gives us a better basis for judgment as to the capacities of the bone-meal ration.

The pigs on which Experiment III was conducted were much superior to those used in the previous experiments. They were four-months-old, pure-bred Duroc Jerseys; they were all sired by the same boar; their dams were all by the same boar, and their grand-dams were closely related; further than this, they had been raised from birth together. These were growing pigs rather than growing and fattening hogs, as in the previous experiments.

The method followed was the same as in the previous experiment, except that the bran-extract was fed in the proportion of 150 cubic centimeters of the extract to each pound of dry feed given. This is the equivalent of a quart of the extract to 6.31 pounds of feed. This lot of pigs was in the best of health throughout the experiment.

The bone-meal was reduced to a fine flour, and fed in this condition from the beginning. We did not experience difficulty in the feeding of the bone in this shape.

The corn ration was not so well relished by these pigs as by the older ones in Experiment II, (Table XIX, page 271), and though these pigs were three months younger and of decidedly better quality, the gains were much more expensive. The younger the pig the less nearly a perfect feed is corn by itself.

With these young pigs there is also a much greater difference between the bran-extract and the low-phosphorus lots in favor of the former; that is, the lack of the ash constituents in the hominy and blood-flour ration was much more keenly felt by the young pigs in this experiment than by the older and larger ones of Experiment II, the younger ones having a less extensive reserve supply of the ash constituents on which to draw to make good the deficiencies of the ration.

As in the previous experiment the bran-extract proved to be slightly laxative, and the hominy and blood-flour without the addition of this supplement, very constipating.

The bran-extract lot ate their food with the keenest relish, though not particularly more so than the bone-flour lot. The low-phosphorus lot did not eat very heartily, and their rough, dead-looking coats gave them an unthrifty look. The corn lot had the poorest appetites of all, and looked the most poorly nourished.

The largest pig in the corn lot was taken out of the experiment, being rendered unfit by an accidental injury. This leaves average weights light in this lot.

TABLE XX: FEEDS AND GAINS IN WEIGHT.

EXPERIMENT II.

Lots	Rations	Digestible nutriment per 100 lbs. gain	Ave. initial weight	Ave. final weight	Number of pigs in lot
		Lbs.	Lbs.	Lbs.	
1	Corn	364.9	125	182.2	5
2	Hominy; blood-flour; bran-extract, (larger amount)	298.6	126.8	200.4	5
3	Hominy; blood-flour; lecithin	231.5	127	220	1
4	Hominy; blood-flour; bran-extract, (smaller amount)	271.7	124	205.2	5
5	Hominy; blood-flour; bone-meal	295.0	126.6	190.8	5
6	Hominy; blood-flour; sodium phosphate	272.5	124.8	203.8	5
7	Check lot; killed		125.2		5

EXPERIMENT III

1	Corn meal	554.2	67	94.25	4
2	Check lot; killed	....	78.6	....	5
3	Hominy; blood-flour bran-extract	330.5	78.4	132.6	5
4	Hominy; blood-flour bone-flour	365.0	79.6	128.2	5
5	Hominy; blood-flour	447.5	78.4	111.0	5

Length of Experiment II, 56 days; of Experiment III, 60 days.

Experiment II. Lot 2, where the bran-extract was fed in the excessive amount, did not make as economical gains in weight as Lot 6, the low-phosphorus lot. Lot 5, the bone-meal lot, also failed to make as economical gains as the low-phosphorus lot. The excess of magnesium in ration No. 2, and the depressing effect of the bone-meal on the digestibility of protein in ration No. 5 are at least in part responsible for the poor showing made by these rations; for Lot 4, with the lower amount of bran-extract, used it to advantage, and made as efficient gains in weight as did Lot 6, the low-phosphorus lot; that it did not make more economical gains in weight, appears to be due to the shortness of the experiment. As is well known, an animal may for considerable periods of time give off more phosphorus in the urine and feces than is present in the food. The effects of phosphorus starvation are not immediately manifest. There are reserves of phosphorus in the body which may be used to supplement a ration which is lacking in this element. This table however, gives no hint as to the character of the increase. It is here that we must hope to find more significant results.

It is apparent, nevertheless, that these various balanced rations, however artificial their character, were all decidedly more efficient than corn alone. The low-phosphorus lot withstood a temporary lack of ash constituents to much better advantage than the corn lot withstood the lack of protein.

Regarding Lot 3, the lecithin pig, we publish these results because we do not wish to suppress any of the evidence, whatever its trend, but the results from a single individual are not fairly comparable with an average of results from five. This evidence is not entirely without weight, however, and so far as it goes is favorable to the belief that lecithin is a valuable nutrient.

Experiment III. The amounts of digestible nutriment eaten per hundred pounds of gain in weight were consistent with the character of the rations. The bran-extract lot received most nearly a normal ration. This lot made the most efficient gains. The bone-flour lot ranked next, it being apparent that, in the amounts fed, this supplement was less efficient than bran-extract to furnish what was lacking in the hominy and blood-flour ration.

The hominy and blood-flour ration, containing an abundance of easily digestible protein and starch, and being in a palatable form, was still decidedly lacking in some constituents necessary to the nourishment of growing pigs.

The ration of corn alone contained less protein, but more of the ash constituents, and was still less efficient than the ration of hominy and blood-flour. In both Experiments II and III the corn ration was the highest in phosphorus and lowest in calcium and in protein.

Experiment II, (Table XXI page 281). The killing of these hogs was conducted at a local slaughter house. The cross-section, instead of being taken at the sixth rib, as in Experiment I, consisted of a three-rib cut taken just behind the shoulder. The thickness of the back-fat was measured on the rear aspect of this section. Samples of the liver and kidney as well as the tenderloin were prepared for analysis, but the chemical study of the cross-section was discontinued, our judgment as to the fatness of the animals being based on the relation of dressed to live-weight, the weight of the leaf-lard, the thickness of the back-fat, and the analyses of the tenderloins.

At the time of killing, the hogs in the six lots fed would have graded as to condition in the market, as follows:

- Lot 1. 1 choice, 1 good, 3 medium, (corn alone).
- “ 2. 3 choice, 1 good, 1 medium, (larger amount of bran-extract).
- “ 3. 1 good, (lecithin).
- “ 4. 4 choice, 1 medium, (smaller amount of bran-extract).
- “ 5. 1 choice, 1 good, 2 medium, 1 common, (bone-meal).
- “ 6. 2 choice, 2 good, 1 medium, (low phosphorus ration).

Three lots of these hogs increased the thickness of the back-fat from one inch to more than two inches in fifty-six days, but none of them doubled the weight of the tenderloin muscles. The leaf-lard and the kidneys also increased rapidly in weight, much more so than the lungs, spleen, heart and liver.

Experiment III. At the time these shotes were killed, the pigs in the four lots averaged in weight between 94.25 and 132.6 pounds; the pigs in the check lot, killed when the experiment began, weighing 78.6 pounds each.

Judging these pigs by the fat-hog standard of the market they would have graded as follows: The corn lot, and the hominy and blood-flour lot, “common”; the bran-extract lot, 1 “choice”, 3 “good”, 1 “common”; and the bone-flour lot, “good”. This last was clearly the fattest lot.

The bran-extract lot, having gained the most in weight, excelled all the other lots in the development of each of the parts observed except that the bone-flour lot excelled it in thickness of back-fat and in weight of leaf-lard, the apparent fatness of these hogs when alive being borne out by the examination of the carcasses.

TABLE XXI: SLAUGHTER RECORDS. AVERAGE WEIGHT OF PARTS.
EXPERIMENT II.

Lots	Rations	Gross dressed weight Pounds	Heart Ounces	Liver Pounds	Spleen Ounces	Lungs Pounds	Leaf-lard Pounds	Kidneys Ounces	Tender- loins Grams	Thickness of back-fat Inches
1	Corn.....	137.33	8.30	2.73	3.20	1.80	5.88	6.03	262.2	1.89
2	Hominy; blood-flour; bran-extract, (larger amount).....	158.87	9.15	3.57	3.93	1.84	5.47	10.53	336.8	2.10
3	Hominy; blood-flour; lecithin.....	165.69	10.63	3.66	4.00	1.43	7.19	8.00	374.0	1.75
4	Hominy; blood-flour; bran-extract, (smaller amount).....	159.81	9.4	3.08	3.13	2.03	6.61	8.75	357.4	2.08
5	Hominy; blood-flour; bone-meal.....	146.49	8.53	3.26	3.16	1.39	5.49	9.18	302.8	1.83
6	Hominy; blood-flour; sodium phosphate.....	160.72	8.88	3.40	3.33	1.81	6.22	8.95	330.6	2.16
7	Check lot.....	92.30	6.46	2.49	2.34	1.33	3.71	4.40	201.6	1.02

EXPERIMENT III.

Lots	Rations	Gross dressed weight Pounds	Heart Ounces	Liver Pounds	Spleen Ounces	Lungs Pounds	Leaf-lard Pounds	Kidneys Ounces	Tender- loins Grams	Thickness of back-fat Inches
1	Corn.....	66.9	4.49	1.77	1.25	1.55	3.58	3.83	121.1	1.46
2	Check lot.....	51.45	4.50	1.83	1.43	.88	1.16	4.25	134.1	1.05
3	Hominy; blood-flour; bran-extract.....	96.4	6.75	2.72	2.06	1.60	4.21	7.75	208.9	1.52
4	Hominy; blood-flour; bone-flour.....	92.7	6.17	2.54	1.62	1.51	4.59	6.05	188.7	1.59
5	Hominy; blood-flour.....	79.1	5.90	2.06	2.04	1.53	3.29	6.05	174.0	1.50

TABLE XXII: RELATION OF PARTS TO DRESSED CARCASS
EXPERIMENT II

Lots	Rations	Percent gross dressed to live weight	Percent of heart	Percent of liver	Percent of spleen	Percent of lungs	Percent of leaf-lard	Percent of kidneys	Percent of tenderloins
1	Corn	75.37	.378	1.988	.146	1.311	4.28	.275	.421
2	Hominy; blood-flour; bran-extract, (larger amount)	79.28	.360	2.247	.155	1.158	2.44	.414	.467
3	Hominy; blood-flour; lecithin	75.31	.401	2.209	.151	.863	4.34	.302	.498
4	Check lot	77.88	.368	1.927	.122	1.270	4.14	.342	.493
5	Hominy; blood-flour; sodium phosphate	76.78	.364	2.225	.135	.949	3.75	.392	.455
6	Hominy; blood-flour; bone-flour	78.86	.345	2.115	.129	1.126	3.87	.348	.453
7	Hominy; blood-flour; bran-extract, (smaller amount)	73.84	.437	2.698	.158	1.441	4.02	.298	.482

EXPERIMENT III

1	Corn	71.0	.420	2.64	.012	2.32	5.35	.359	.399
2	Check lot	66.5	.547	3.55	.017	1.71	2.25	.516	.575
3	Hominy; blood-flour; bran-extract	72.7	.438	2.82	.013	1.66	4.37	.502	.478
4	Hominy; blood-flour; bone-flour	72.3	.416	2.74	.011	1.63	4.95	.410	.449
5	Hominy; blood-flour	71.3	.466	2.60	.016	9.31	4.16	.480	.485

Lot 1, in Experiment III, fed on corn alone, contained but four pigs, one of the original five, the largest, having been removed early in the experiment because of a mechanical injury; the other lots contained five pigs each.

Experiment II. The low-phosphorus lot, No. 6, (see above table), dressed a high percentage of carcass to live-weight and, as will be seen in Table XXI, page 281, had the thickest back-fat.

The corn lot dressed a low percentage of carcass to live-weight, on account of the small amount of increase put onto the carcass, though as a rule corn produces a carcass which, because of small viscera and thick fat, dresses out a high percentage of carcass to live-weight. This lot was low in percentage of tenderloin and high in percent of leaf-lard.

The lungs of the corn lot were heavier in proportion to the carcass, and the kidneys were lighter, than in any other lot.

It will be noted that the check lot had a larger percentage of heart, liver, spleen, and lungs than any of the lots that were fed, but the kidneys of the lots which received the balanced rations were heavier in comparison with the weight of the carcass than in the check lot; this doubtless being due to the protein in these rations, for the corn lot and this one only, did not increase its percentage of kidneys during the course of the experiment.

Experiment III. These lots of hogs each dressed about the same percentage of carcass to live-weight. The bran-extract lot exceeded the bone-flour lot, even though not so fat. It would seem that the excess of muscle in the bran-extract lot more than offset the excess of fat in the bone-flour lot. The corn lot, and the hominy and blood-flour lot, which received the low-protein and the low-phosphorus rations respectively dressed the lowest percentages of carcass to live-weight, since neither of these rations was well adapted to the production of growth.

The carcasses of the corn-fed hogs contained the largest percent of leaf-lard and lungs and the smallest percent of kidneys and tenderloin muscles.

Experiment II, (Table XXIII, page 284). The percent of gain in the live-weight was about the same in Lots 4 and 6, the bran-extract and the low-phosphorus lots. Both of these gained decidedly more rapidly than did the corn lot, No. 1. Even the difficulty which we had with the feeding of bone-meal to Lot 5 did not prevent this lot from exceeding the corn lot in increased weight. The hearts, livers, kidneys and tenderloin muscles of these corn-fed pigs gained very poorly. This lot gained fairly well, however, in thickness of back-fat and in weight of leaf-lard.

It is worthy of note that the bone-meal lot, No. 5, while gaining 51 percent in live-weight, gained 105 percent in the ash of the bones and 48.5 percent in the weight of the muscles. This lot and the corn lot were the only ones which did not gain in muscle as fast as in live-weight.

Experiment III. The corn lot seems to have gained the least in live-weight, liver, spleen, kidneys and tenderloin muscles, but the loss of one pig renders the figures with reference to this lot of slightly uncertain value.

The bran-extract lot excelled the bone-flour and the low-phosphorus lots in percentage of gain in live-weight, heart, liver, spleen, lungs, kidneys and tenderloin muscles.

The bone-flour lot, however, excelled in the percentage of increase in leaf-lard, thickness of back-fat, and in the ash of the bones. This lot ate practically as much feed as the bran-extract lot, but probably because of the unavailability of bone phosphates for muscular growth, the digested nutriment was laid down as fat rather than as proteid increase.

The hominy and blood-flour, or low-phosphorus lot, was at a conspicuous disadvantage, as compared with the bran-extract and the bone-flour lots, in the formation of bone, the ration providing very little indeed that the pigs seem to have been able to use for this purpose. The ability of this lot to lay on fat and muscle was not hindered to nearly so great an extent as was its ability to grow bone.

TABLE XXIII: PERCENT OF INCREASE IN WEIGHTS AND MEASUREMENTS OF PARTS.
EXPERIMENT II

Lots	Rations	Live weight	Heart	Liver	Spleen	Lungs	Leaf-lard	Kidneys	Tenderloins	Thickness of back-fat	Ash of humerus
1	Corn.....	45.76	28.68	8.64	36.7	35.3	58.9	37.4	30.25	85.3	44.7
2	Hominy; blood-flour; bran-extract, (larger amount).....	58.04	39.9	41.7	65.8	36.3	45.5	136.1	64.93	104.0	44.3
3	Hominy; blood-flour; lecithin.....	73.23	62.3	44.7	68.8	6.0	91.0	79.4	82.89	70.0	68.6
4	Hominy; blood-flour; bran-extract, (smaller amount).....	65.48	46.9	24.7	34.9	53.8	80.1	100.7	78.97	106.0	61.2
5	Hominy; blood-flour; bone-meal.....	50.71	30.6	29.4	33.3	3.0	46.3	106.3	48.50	77.7	104.9
6	Hominy; blood-flour; sodium phosphate.....	63.30	37.9	37.1	42.9	36.1	68.1	103.9	64.48	111.8	56.6

EXPERIMENT III

1	Corn*.....	40.7	19.7	12.5	-9.1	108.9	224.3	-2.3	7.36		41.6
3	Hominy; blood-flour; bran-extract.....	69.1	50.0	49.0	44.6	81.8	262.9	82.4	55.8	44.3	40.5
4	Hominy; blood-flour; bone-flour.....	61.0	35.3	37.4	12.3	69.7	292.3	40.8	37.0	50.0	43.6
5	Hominy; blood-flour.....	41.6	31.1	12.9	43.2	73.9	183.6	42.4	29.8	43.2	3.2

* Computed with reference to four of the pigs of the check lot.

TABLE XXIV: INCREASE IN WEIGHT OF VARIOUS PARTS AND ORGANS IN RELATION
TO GAIN IN LIVE-WEIGHT.
EXPERIMENT II.

Lots	Rations	Heart	Liver	Spleen	Lungs	Leaf-lard	Kidneys	Tender-loin	Thickness of back-fat	Ash of humerus
1	Corn.....	.627	.211	.802	.771	1.287	.817	.661	1.864	.977
2	Hominy; blood-flour; bran-extract, (larger amount).....	.687	.718	1.134	.625	.784	2.345	1.119	1.792	.763
3	Hominy; blood-flour; lecithin	.851	.610	.939	.082	1.243	1.084	1.132	.956	.937
4	Hominy; blood-flour; bran-extract, (smaller amount).....	.716	.377	.533	.822	1.223	1.538	1.206	1.619	.935
5	Hominy; blood-flour; bone-meal.....	.603	.580	.657	.059	.913	2.096	.956	1.532	2.069
6	Hominy; blood-flour; sodium phosphate.....	.599	.586	.678	.570	1.076	1.641	1.019	1.766	.894

EXPERIMENT III.

Lots	Rations	Heart	Liver	Spleen	Lungs	Leaf-lard	Kidneys	Tender-loin	Thickness of back-fat	Ash of humerus
1	Corn.....	.484	.307	— .224	2.675	5.511	— .057	.181	1.516	1.022
3	Hominy; blood-flour; bran-extract.....	.724	.709	.645	1.184	3.805	1.192	.808	.641	.586
4	Hominy; blood-flour; bone-flour.....	.580	.613	.202	1.143	4.792	.667	.607	.820	.715
5	Hominy; blood-flour.....	.748	.310	1.039	1.776	4.413	1.019	.716	1.039	.077

Experiment II. The most significant data of the experiment are set forth in the preceding table. The large increase in the weight of the leaf-lard and in the thickness of the back-fat indicate a large percentage of fat in the increase of live-weight, the corn lot naturally leading in these regards, and being last in gain of muscle. This lot also gained very little in weight of liver and kidneys, in relation to gain in live-weight.

The increase in the low-phosphorus lot, No. 6, greatly exceeds the corn lot in percent of liver, kidneys and tenderloin muscles. The lack of protein and calcium in the corn seems to have been more severely felt than the lack of phosphorus and potassium in the low-phosphorus ration.

The increase in the bran-extract lot, No. 4, was higher in percent of heart, lungs, leaf-lard and tenderloin muscles than in the low-phosphorus lot. The rations being otherwise the same, it must be concluded that the bran-extract furnished valuable nutrients which were lacking in the low-phosphorus ration, these probably being phosphorus and potassium.

In the bone-meal lot the gain in weight was less largely muscle than in the low-phosphorus lot, while at the same time the proportion of bone-ash in the increased weight seems to have been three times as great. The addition of bone-meal to the ration appears not to have added to its tendency to produce muscle.

The bran-extract, however, did cause an improvement in the hominy and blood-flour ration, as regards both bone and muscle formation. Bran-extract seems to have a capacity that bone-meal does not to take part in proteid increase.

Experiment III. The bone-flour lot produced a smaller proportion of muscle in the increase in weight than the low-phosphorus lot, the rations differing only with regard to the presence of the bone-flour. Obviously the composition of the increase is not rendered more largely muscle because of the addition of bone-flour to the hominy and blood-flour ration. The bran-extract ration, however, produced a decidedly greater proportion of muscle in the increase than did any other lot. We incline to ascribe this difference in the usefulness of these supplements most largely to the differences in the compounds of phosphorus contained in them.

The corn ration, with its deficiency of protein, produced a much smaller proportion of muscle in the increase than did any other ration.

The proportion of bone-ash in the increase was greater with the corn lot than with the bone-flour lot. The corn lot received more phosphorus than any of the other lots in this experiment. The low-phosphorus ration made peculiarly little increase in the ash of the bone, and the addition of bran-extract to this ration was of decided benefit in the deposit of ash in the bones.

The two lots which produced the greatest proportion of back-fat in the increase are the corn, and the low-phosphorus lots, these being the most abnormal rations, and those in which a lack either of protein, or of ash constituents, was disadvantageous to the construction of bone and muscle.

The slightly smaller proportion of muscle in the increase in the bone-flour lots, than in the low-phosphorus lots, in both these experiments, gives evidence of the depressing effect which calcium phosphate has on the digestibility of protein.

Experiment II, (Table XXV, page 288). The bones of the bone-meal lot, No. 5, were larger than in other lots, as is evidenced by their volume; the amount of ash was also greater; the ash per cubic centimeter of volume was greater, and the breaking strength greater than in other lots. Clearly bone-meal in the ration contributes to the nourishment of the bones, even though it appears not to be useful in muscle building.

The lack of protein in corn tends to reduce the size, density and strength of the bones, as is seen by comparing Lots 1 and 6, the latter containing more protein, but less ash, than the former.

Experiment III. The volume of the bones in the different lots differed but little. The smallness of the bones of the corn lot was partially due to the fact that the largest pig had been removed from this lot.

The bone-flour ration did not produce as large bones as the bran-extract ration, though the ash per cubic centimeter of volume was much greater; that is, the bone was denser. The bone produced by the low-phosphorus ration was less dense than any other.

The density of the bone of the corn, and the bone-flour lots was about alike.

The breaking strength was least with the low-phosphorus lot while the bran-extract, and bone-flour lots both ranked higher than the corn lot. It should be borne in mind that the bone-flour lot in this experiment received much less phosphorus than did the corn lot, but its greater amount of calcium appears to have been of benefit in the production of strong bone.

TABLE XXV: DATA CONCERNING DEVELOPMENT OF BONES
EXPERIMENT I.

Lots	Rations	Volume of each humerus C. C.	Ash in each humerus Grams	Ash per c. c. Grams	Breaking strength Lbs.	Length Cm.	Longer transverse diameter Cm.	Shorter transverse diameter Cm.
1	Corn.....	108.0	32.92	.3048	509	13.88	2.25	1.63
2	Hominy; blood-flour; bran-extract, (larger amount).....	111.8	33.33	.2981	575	13.68	2.23	1.67
3	Hominy; blood-flour; lecithin.....	118.0	38.97	.3303	736	13.70	2.20	1.66
4	Hominy; blood-flour; bran-extract, (smaller amount).....	117.6	36.39	.3094	676	13.74	2.34	1.68
5	Hominy; blood-flour; bone-meal.....	121.3	46.22	.3811	791	14.00	2.28	1.71
6	Hominy; blood-flour; sodium phosphate.....	112.5	35.59	.3164	624	13.90	2.33	1.69
7	Check lot.....	78.9*	22.80*	.2890*				

EXPERIMENT III.

1	Corn;.....	74.6	23.82	.319	502	13.1	1.83	1.37
2	Check lot.....	65.9	19.93	.3024	440	11.64	1.75	1.30
3	Hominy; blood-flour; bran-extract.....	100.1	28.01	.280	641	14.46	1.98	1.51
4	Hominy; blood-flour; bone-flour.....	94.4	28.97	.307	606	13.46	2.08	1.46
5	Hominy; blood-flour.....	93.7	20.56	.219	426	13.56	1.95	1.41

*Computed as a basis for reckoning increase made in other lots.

TABLE XXVI: ANALYSES OF TENDERLOIN MUSCLES
EXPERIMENT II

Lot	Rations	Water	Protein	Fat	Ash	Phosphorus	Water in fat-free meat	Fat in water-free meat	Proportion of phosphorus to protein	Proportion of ash to protein	Phosphorus in ash
		Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
1	Corn	73.51	19.73	5.17	1.09	.264	77.52	19.52	1.34	5.52	24.22
2	Hominy; blood-flour; bran-extract, (larger amount)	73.62	18.85	5.17	1.13	.195	77.63	19.60	1.04	6.00	17.35
3	Hominy; blood-flour; lecithin	74.63	15.78	4.27	1.10	.352	77.97	16.83	2.23	6.98	32.00
4	Hominy; blood-flour; bran-extract, (smaller amount)	72.74	20.67	4.22	1.21	.252	75.10	15.48	1.22	5.85	20.83
5	Hominy; blood-flour; bone-meal	72.83	20.13	5.12	1.08	.233	76.77	18.85	1.16	5.37	21.57
6	Hominy; blood-flour; sodium phosphate	72.87	20.74	5.14	1.10	.264	76.82	18.95	1.27	5.30	24.00
7	Check lot	73.57	18.53	4.97	1.10	.247	77.42	18.80	1.33	5.93	22.45

EXPERIMENT III

Lot	Rations	Water	Protein	Fat	Ash	Phosphorus	Water in fat-free meat	Fat in water-free meat	Proportion of phosphorus to protein	Proportion of ash to protein	Phosphorus in ash
		Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
1	Corn	73.39	17.68	6.16	1.07	.228	77.21	23.15	1.29	6.05	21.31
2	Check lot	76.35	19.42	3.04	1.13	.238	76.74	12.85	1.23	5.30	21.06
3	Hominy; blood-flour; bran-extract	73.74	21.85	3.90	1.03	.195	76.73	14.85	.81	4.71	18.93
4	Hominy; blood-flour; bone-flour	73.20	18.30	4.46	1.12	.222	76.62	16.64	1.21	6.12	19.82
5	Hominy; blood-flour	72.81	20.39	4.52	1.15	.228	76.26	16.62	1.12	5.64	19.83

The analyses of the muscles, livers and kidneys involved much work which does not yield results of immediate practical value. These data, however, will assist us in learning how these tissues and organs vary in composition, and in some cases probable causes and interesting associations of factors are observed. After a sufficient accumulation of evidence we shall be able to say just how foods vary the composition of animals, and to interpret and apply the results in a practical way; but we must establish the facts before attempting to draw conclusions.

The tenderloin muscles produced by Lot 1, the corn lot, in Experiment II, (Table XXVI, page 289), were characterized as in Experiments I and III by their high fat and low protein content, and by the high water-content of the fat-free meat.

In Experiment II there is more phosphorus in the muscles of the corn-fed lot, in the meat as a whole, and in the protein, than in the check lot, No. 7, which was not fed.

In Experiment III, however, the condition is reversed; in the corn lot, No. 1, there being less phosphorus in the meat as a whole, and in the protein, than in the check lot, No. 2. This is partially due to the greater age of the pigs in Experiment II. They thrive to much better advantage on corn alone than did the younger pigs in Experiment III. Further, the check lot in Experiment III had been raised on foods containing more phosphorus than those on which the check lot in Experiment II had been raised.

The low-proteid, high-phosphorus character of the corn ration, as compared with these others, shows itself in the composition of the muscles.

In both Experiments II and III the percent of phosphorus in the meat as a whole is the same in the corn lot and the low-phosphorus lot, but the proportion of phosphorus to protein is greater, and the percent of phosphorus in the ash is greater in the corn lots in both experiments, than in the low-phosphorus lots, because of the smaller amount of protein and of ash in the muscles of the corn-fed pigs. These differences are less in Experiment II, where the sodium phosphate was fed to the low-phosphorus lot, than in Experiment III where the hominy and blood-flour were fed alone. In both experiments the gain in muscle was much greater on the low-phosphorus ration, which was high in protein, than on the corn ration, which was much higher in phosphorus, but lower in protein.

In both Experiments II and III there is quite decidedly less phosphorus in the meat as a whole, in the protein, and in the ash, in the muscles of the bran-extract lots than in the corn lots, in fact these bran-extract lots are lower in the phosphorus in the muscles

than any other, without exception, in either experiment, while at the same time these rations caused the greatest increase in the weight of these muscles. (Table XXIII, page 284).

The bone-meal and the low-phosphorus lots in these two experiments furnish a most interesting comparison.

Adding bone-meal to the ration of hominy and blood-flour increased the proportion of ash to protein in the muscles produced; did not increase the percentage of phosphorus, either in the muscle or in the ash of the muscle; and decreased the percentage of protein in the muscles.

In both experiments the undetermined constituents were slightly greater in amount with the bone-meal lot than with the low-phosphorus lot, which, assuming the work to be correct, might indicate a higher percentage of glycogen.

Bran-extract has a tendency to produce muscles containing a low percentage of phosphorus in the ash. In Experiment II, the bran-extract lots were lower than others in this regard, the lot receiving the most bran-extract being the lowest, and in Experiment III the bran-extract lot was again lowest of all. In both experiments the lot having the least phosphorus in the meat had received bran-extract. The rations, however, containing bran-extract were high in phosphorus.

The results from the analysis of the meat samples from the one pig which received lecithin with the basal ration of hominy and blood-flour, and which constituted Lot 3, in Experiment II, are regarded as having greater value than the weights of organs of this pig, and data regarding gains in weight. It would seem from these figures that the lecithin had tended to the production of muscles containing a high moisture content, low percentage of protein and of fat, very high percent of phosphorus, high percent of water in the fat-free meat, high percent of ash, and high proportion of phosphorus to protein, and high percent of phosphorus in the ash.

In the kidneys the lecithin lot contained a low percent of water, and was high in protein and in phosphorus, but the proportion of phosphorus to protein was not unusual. (Table XXVII, page 292).

The liver of this pig analyzed high in phosphorus, and high in the percent of phosphorus in the ash. (Table XXVIII, page 294).

Hence we may say regarding the lecithin lot, that the phosphorus content of the meat as a whole, in the muscles, was much higher than in any other lot; in the liver it was as high as in any lot, and in the kidneys it was exceeded only by the check lot which was not fed. The small amount of lecithin fed has produced these marked effects only because the basal ration to which it was added was exceedingly low in phosphorus compounds.

TABLE XXVII: ANALYSES OF KIDNEYS.
EXPERIMENT II.

Lots	Rations	Water	Protein	Fat	Ash	Phos- phorus	Water in fat-free meat	Fat in water-free meat	Proportion of phos- phorus to protein	Proportion of ash to protein	Phos- phorus in ash
		Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
1	Corn.....	78.21	15.78	3.07	1.17	.232	80.69	14.09	1.47	7.41	19.83
2	Hominy; blood-flour; bran-extract, (larger amount).....	80.68	14.34	2.65	1.02	.243	82.88	13.72	1.69	7.11	23.82
3	Hominy; blood-flour; lecithin	78.80	16.38	2.89	1.15	.258	81.15	13.63	1.58	7.02	22.43
4	Hominy; blood-flour; bran-extract, (smaller amount).....	79.99	15.62	2.57	1.10	.250	82.10	12.84	1.60	7.04	22.73
5	Hominy; blood-flour; bone-meal.....	79.27	15.49	2.94	1.11	.205	81.67	14.18	1.32	7.17	18.47
6	Hominy; blood-flour; sodium phosphate.	80.55	14.56	2.72	1.12	.234	81.16	13.98	1.61	7.69	20.90
7	Check lot.....	78.80	16.83	1.99	1.20	.262	80.40	9.38	1.57	7.13	21.83

EXPERIMENT III

Lots	Rations	Water	Protein	Fat	Ash	Phos- phorus	Water in fat-free meat	Fat in water-free meat	Proportion of phos- phorus to protein	Proportion of ash to protein	Phos- phorus in ash
		Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
1	Corn.....	76.70	17.07	4.95	1.14	.313	80.69	21.24	1.83	6.68	27.46
2	Check lot.....	80.32	14.37	2.11	1.12	.249	82.05	10.72	1.73	7.79	22.23
3	Hominy; blood-flour; bran-extract	79.78	15.79	3.41	1.11	.249	82.60	16.86	1.58	7.03	22.43
4	Hominy; blood-flour; bone-flour.....	77.18	16.01	3.92	1.14	.318	80.33	17.18	1.99	7.12	27.90
5	Hominy; blood-flour	77.84	17.00	3.91	1.07	.294	81.01	17.64	1.73	6.29	27.48

The kidneys from the corn-fed pigs, (Table XXVII, page 292), contained less water and more fat, in both Experiments II and III, than from any other lots. In both experiments they were high in protein and in ash. The phosphorus content of the kidneys of the young pigs of Experiment III, was much higher in the corn lot, the the bone-flour lot, and the low-phosphorus lot, but lower in the check lot, than in the corresponding lots of older pigs in Experiment II.

The kidneys of the bran-extract lots were, in both Experiments II and III, lower in fat than any except the check lot; were high in percent of water, and higher than any other lots in percent of water in the fat-free meat; were low in fat in the water-free meat; low in ash, and in proportion of ash to protein.

The bone-meal ration produced kidneys that were high in fat, both on the basis of the whole meat and the water-free meat, and in both Experiments II and III were higher in fat than in the bran-extract, the low-phosphorus, and the check lots.

The livers of the corn-fed lots, (Table XXVIII, page 294), were characterized by only two conditions that hold good through both experiments; in each they are comparatively low in ash and in phosphorus.

The livers of the bran-extract lots are characterized by being high in percent of phosphorus, and high in percent of phosphorus in the ash. Compared with the bone-meal lots, the bran-extract lots, No. 4 in Experiment II, and No. 3 in Experiment III, were the higher in both experiments in water, protein, fat, phosphorus, water in the fat-free meat, fat in the water-free meat, and phosphorus in the ash. The phosphorus and ash in the protein were higher in the bone-meal lots.

Since water, fat and protein were all higher in the livers of the bran-extract lots than in the bone-meal lots, this would indicate a higher glycogen content in the livers of the latter, or errors in analytical work.

The livers of the low-phosphorus lots, No. 6 in Experiment II and No. 5 in Experiment III, were high in percentage of protein and ash, but low in water and phosphorus, and in the proportion of ash and of phosphorus to the protein.

TABLE XXVIII: ANALYSES OF LIVERS.
EXPERIMENT II.

Lots	Rations	Water	Protein	Fat	Ash	Phos- phorus	Water in fat-free meat	Fat in water-free meat	Proportion of phos- phorus to protein	Proportion of ash to protein	Phos- phorus in ash
		Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
1	Corn	74.24	18.83	2.81	1.27	.320	76.39	10.91	1.70	6.74	25.20
2	Hominy; blood-flour; bran-extract, (larger amount)	73.52	17.19	2.46	1.37	.356	75.37	9.29	2.07	7.97	26.00
3	Hominy; blood-flour; lecithin	71.98	18.72	2.90	1.29	.364	74.13	10.35	1.94	6.89	28.22
4	Hominy; blood-flour; bran-extract, (smaller amount)	71.96	20.13	3.01	1.32	.364	74.19	10.74	1.81	6.56	27.58
5	Hominy; blood-flour; bone-meal	71.81	19.45	2.65	1.39	.361	73.76	9.40	1.85	7.11	25.97
6	Hominy; blood-flour; sodium phosphate	72.05	20.68	2.85	1.34	.324	74.16	10.20	1.57	6.51	24.18
7	Check lot	71.48	14.61	1.84	1.17	.291	72.82	6.45	1.99	8.01	24.87

EXPERIMENT III

Lots	Rations	Water	Protein	Fat	Ash	Phos- phorus	Water in fat-free meat	Fat in water-free meat	Proportion of phos- phorus to protein	Proportion of ash to protein	Phos- phorus in ash
		Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
1	Corn	70.77	16.08	2.32	1.21	.338	72.45	7.94	2.10	7.52	27.93
2	Check lot	71.21	18.12	3.01	1.33	.338	73.42	10.46	1.87	7.34	25.41
3	Hominy; blood-flour; bran-extract	71.65	20.44	2.49	1.30	.367	73.48	8.78	1.80	6.36	28.23
4	Hominy; blood-flour; bone-flour	70.43	19.31	2.03	1.30	.366	71.90	6.87	1.90	6.73	28.15
5	Hominy; blood-flour	70.64	20.97	2.26	1.34	.346	72.27	7.70	1.65	6.39	25.82

CONCLUSIONS FROM EXPERIMENTS II AND III.

Experiment II, Lot 1, (corn alone). By reference to Table XIX, page 271, we see that Lot 1 received the lowest proportion of proteid to non-proteid food, the smallest amount of calcium and of sulphur, but more phosphorus, than any lot except Lot 2, (larger amount of bran-extract). The ration contained a greater excess of mineral acid over mineral base than any other.

This ration of corn alone produced the least increase in live weight, (Table XX, page 278), the smallest and weakest bones, (Table XXV, page 288), the smallest percent of liver, kidney and muscle in the increased weight, (Table XXIV, page 285), the smallest gain in the weight of the heart, and the largest increase in the leaf-lard and back-fat, (Table XXIII, page 284).

The weakness of the bones is attributed principally to the deficiency of corn in calcium and in protein, and to the considerable excess of mineral acid over mineral base in this feed. The great excess of magnesium in proportion to calcium is also probably a factor in the inefficiency of corn to produce bone.

The low proportion of proteid tissues and high proportion of fat in the increase is due mostly to the low protein content of this feed; and proteid increase was also doubtless interfered with by the excess of acid mineral elements.

Experiment III, Lot 1, (corn alone). The corn ration, in Experiment III, (Table XIX, page 272), was low in protein and calcium but high in phosphorus in comparison with these other rations. It seemed to be poorly adapted to the production of tissue, the gains in live-weight, muscles and internal organs being generally very low. It was better adapted to the production of fat, of lungs, and of ash in the bones than to other purposes. (Table XXIII, page 284). We should bear in mind, however, that corn is a very poor bone food, and that it excelled in this experiment only because the other rations were still less efficient. The high fat production seems to be due principally to the low proportion of protein in the ration, the animal being forced to make fat through its inability to construct proteid growth from the nutrients provided. The low calcium content of the ration was quite unfavorable to bone formation. The comparative abundance of phosphorus and the deficiency in protein, which limited the use of phosphorus in proteid increase, accounts, in part, for the considerable gain which there was in the ash of the bones, the ash per cubic centimeter of volume being higher than in other lots. (Table XXV, page 288).

In both Experiments II and III the proportions of lungs, leaf-lard and back-fat were all higher in the increase made by the corn ration than with the balanced rations, but the proportions of kidneys and muscles in the increase with the corn ration were lower than with the other rations, which contained more protein.

In Experiment I, (Table XI, page 261), the same relations exist in the development of these organs, between the corn rations and the balanced rations, except that the increase in lungs is comparatively less than in the balanced rations.

The association of small kidneys and muscles, with thick back-fat and heavy leaf-lard, in the lots which received corn alone, is apparently simply the result of the lack of protein in the ration.

The muscular tissue produced from corn was characterized by high fat and low protein contents, and by high water content of the fat-free meat.

The kidneys of the corn-fed pigs were low in water content, and higher in fat than the kidneys from other lots.

The livers of the corn-fed pigs were low in ash and in phosphorus.

The younger pigs used in Experiment III did not thrive on this corn ration nearly so well as did the older pigs of Experiment II.

Experiment II, Lot 2, (hominy, blood-flour and bran-extract, larger amount). This lot which received the larger amount of bran-extract, received about the same organic nutrients as Lot 4, which received a very much smaller amount of bran-extract; hence we may look to differences in the mineral nutrients for explanation of differences in results. The lot which received the larger amount of the extract received in its ration more mineral nutriment than the lot receiving less of this extract, and since the balance of mineral acid to base in bran-extract is in favor of the basic elements, ration No. 2, containing the larger amount of this food, contained a smaller excess of mineral acid over mineral base than did ration No. 4. These observations are all in favor of Lot 2; but this lot of pigs was constantly in discomfort, and the results show that something was wrong with the ration. The bones of the pigs were less in volume, (Table XXV, page 288); the ash per cubic centimeter of volume of bones was less; the breaking strength of the bones was much less, and the measurements of length and diameter were less where the larger amount of bran-extract was used.

The gain in live weight, heart, lungs, leaf-lard, muscles and back-fat was less, and the gain in liver, spleen and kidneys decidedly greater where the larger amount of the bran-extract was used. (Table XXIII, page 284).

These differences seem to be due to the great excess of magnesium over calcium in bran-extract, which resulted in a withdrawal of calcium from the body; it is possible that the large amount of phytin in the bran-extract also contributed to the unfavorable results, though at least in moderate quantities this compound is a valuable nutrient.

Experiment II, Lot 3, (low-phosphorus basal ration and small amount of lecithin). This lot, which received a small amount of pure lecithin in the feed, was composed of but a single pig, and we hesitate to draw conclusions from results with a single individual; we would call attention, however, to the facts that this ration, differing from that fed to Lot 6 only in that the latter received as sodium phosphate the same amount of phosphorus that the former received as lecithin, produced greater gain in live-weight at a lower expenditure of food and the percent of gain in heart, liver, spleen, leaf-lard and muscles, and in the ash, volume, ash per cubic centimeter of volume and breaking strength of the bones was also greater with this ration containing lecithin.

The gain in the lungs and kidneys was less where lecithin was fed than where the phosphorus was fed as sodium phosphate. These facts may indicate high proportion of storage of the nutrients in the body and, in consequence, low eliminative activity.

These observations, coupled with the more rapid and economical gain in weight, and the greater increase in the growth of muscles, visceral organs and bones, might be considered to indicate that the lecithin had exercised a very favorable influence in the animal economy. These deductions are suggested because, though this evidence is insufficient for their establishment, subsequent work by the author at the Ohio Station sustains these observations. They appear to be in harmony with the facts. It may be well, however, to call attention to the fact that these results were obtained with rations which were very low in phosphorus. We have as yet no evidence to warrant the supposition that any such results would have attended the addition of lecithin to a normal ration, or that lecithin is the only organic phosphorus compound possessing the same capacities. Ten percent of the phosphorus of this low-phosphorus ration was in the shape of lecithin.

The pig selected for this ration was not apparently in any way a superior individual. There was no difference of opinion on this point among those who observed the progress of the experiment.

The muscles of the pig which received lecithin were characterized by a high percent of water and of ash; and of phosphorus, in the tissue as a whole, and also in the ash of the muscle.

The kidneys were low in water content.

The liver, like the muscles, was high in its content of phosphorus, both in the tissue as a whole and in its ash.

Experiment II, Lot 4, (smaller amount of bran-extract) and Lot 5, (bone-meal). Lot 4, which received the smaller amount of bran-extract, gained in weight rapidly and economically, (Table XX, page 278), and there was every evidence that these pigs were well nourished.

The most instructive comparison is between this lot and Lot 5, which received bone-meal with its basal ration. The proportion of protein to non-proteid organic nutrients was the same in both rations. The most marked differences are in the phosphorus compounds used as supplements. In Lot 4 the bran-extract contained a very large amount of phosphorus in an organic combination known as phytin. The ration fed to Lot 5 contained somewhat more phosphorus than the above, but two-thirds of it was inorganic bone phosphate.

This bone-meal ration contained six times as much calcium, but only one-third as much magnesium, as the bran-extract ration, No. 4, and also contained a smaller excess of mineral acid over mineral base.

Lot 4, which received the organic phosphorus compound from wheat bran, made greater and more economical growth and produced a larger percentage of muscle and fat in the increase, (Table XXIV, page 285), but the development of the bones was very decidedly less, (Table XXV, page 288), being excelled in volume, total ash, ash per cubic centimeter of volume, breaking strength and length, and in one of the two transverse diameters.

The fact that the bone-meal lot received the most calcium and phosphorus explains in part their greater development of bone, but renders still more decisive their failure to develop muscle. Bone-meal seems not to be able, as is bran-extract, to contribute to the development of proteid increase.

The lower potassium content of the bone-meal ration, (Table XIX, page 271), may be a factor in its inferiority for muscle production, since potassium is a prominent constituent of the ash of flesh.

We should also bear in mind that the bone-meal lot ate 14 percent less feed than the bran-extract lot, No. 4, but that at the same time the bones produced were both denser and stronger.

The bone-meal ration contained more than twice as much phosphorus as the low-phosphorus ration, No. 6, but produced a smaller proportion of muscle in the increased weight. This is probably due most largely to the unavailability of the phosphorus of bone for muscle

formation, but partially to the lowered digestibility of the protein of this ration because of the presence of phosphorus in this condition. This latter fact has been observed by a number of investigators, among them LeClerc and Cook*.

Experiment III, Lot 3, (bran-extract) and Lot 4, (bone meal). In this experiment the bran-extract ration was consumed in the same amount as the bone-flour ration, and the nutritive ratio and amount of protein were the same. These rations differed, however, as to the amount and kind of ash constituents, the bran-extract ration containing decidedly more potassium and phosphorus but very much less calcium. (Table XIX, page 272).

This excess of calcium in the bone-meal ration increased the amount and proportion of ash in the increase, and the ash per cubic centimeter of volume of bone, but seems not to have been of other conspicuous advantage. (Table XXIV, page 285).

The deficiency of potassium and phosphorus, as compared with the bran-extract ration, is reflected in the gain in live-weight, muscle, heart, liver, spleen, lungs and kidneys. In each case the bran-extract lot exceeded the bone-flour lot. (Table XXIII, page 284). What then did the bone-flour lot do with that amount of nutriment which the bran-extract lot made into the greater amount of protein in the increase? Judging by appearances we would say that they made it into fat, for they looked very much fatter, and in accordance with this idea we find that the leaf-lard was heavier, and the back-fat thicker in this lot. (Table XXI, page 281). There was the same amount of phosphorus in the hominy and blood-flour in both the bran-extract and the bone-flour rations, (Table XIX, page 272), but the phosphorus in the bran-extract was greater in amount than the phosphorus in the bone flour, and was present in a very different compound, in the former case being mostly phytin, and in the latter case being mostly the tri-calcic salt of phosphoric acid.

While this bran-extract produced maximum muscular increase, the muscles were characterized by a lower phosphorus content than is found in any other lot.

The kidneys of the bran-extract pigs were very low in fat, and high in water, both in the tissue as a whole and in the fat-free substance. The kidneys were also low in ash in the tissue as a whole, and also low in proportion of ash to protein.

The livers of this lot were characterized by high contents of phosphorus, both in the tissue as a whole, and in the ash.

* LeClerc and Cook: Journ. Biol. Chem. vol. 2, p. 203.

The addition of bone-meal to the low-phosphorus ration increased the proportion of ash to protein in the muscles produced, by decreasing the percentage of protein. The percentage of phosphorus was not increased either in the muscles, or in the ash of the muscle.

The kidneys were characterized by a high fat content.

Experiment II, Lot 6, ("low-phosphorus lot," basal ration and small amount of sodium phosphate). The "low-phosphorus" ration, No. 6, was also low in calcium, (Table XIX, page 271), but did not contain, as apparently did the corn, and bran-extract rations, an excessive proportion of magnesium to calcium.

There are in the results from this ration no such marked indications that the pigs suffered from a lack of phosphorus as with the same ration in Experiment III, where the pigs were considerably younger, and where no sodium phosphate was fed with the hominy and blood-flour.

The 43.5 grams of phosphorus fed to this low-phosphorus lot as sodium phosphate constituted 10 percent of the total amount of phosphorus in the ration. Its ready solubility may have given it a value out of proportion to its amount, in comparison with the total phosphorus in the ration.

Comparing this low-phosphorus lot, No. 6, with the bran-extract lot, No. 4, we find that the gain in weight was essentially the same, and the efficiency of the two rations to cause gain in weight was the same, (Table XX, page 288). We do see some evidence of the lack of phosphorus, calcium and potassium, in ration No. 6, however, in the smaller gain in the volume and ash of the bones, in their lower breaking strength, (Table XXV, page 288), and in the somewhat smaller proportion of muscle in the increase, (Table XXIV, page 285).

Shotes with well-grown bones and muscles seem to be able to stand a moderate shortage in the ash constituents of the ration for 56 days, without any marked effect. The younger pigs of Experiment III felt the lack of the ash constituents of this ration, the same except for the lack of the sodium phosphate, very much more keenly.

Experiment III, Lot 5, ("low-phosphorus" basal ration). The "low-phosphorus" ration, No. 5, (Table XIX, page 272), consisting of hominy and blood-flour, contained decidedly less calcium, potassium and phosphorus than either the bran-extract or the bone-flour rations. The food was also eaten in smaller amount, but had the same nutritive ratio as these other two. In potassium and phosphorus this ration was much lower than the corn ration, but was decidedly higher in protein and calcium. The greater

quantities of calcium and of protein, however, did not compensate for the lack of phosphorus and potassium, for the gain in the ash of the bones was almost nothing; very much less than in the corn lot. (Table XXIII, page 284). The ash per cubic centimeter of volume of the bones was less than with other lots, and was much less than in the check lot, which was not fed. (Table XXV, page 261).

The most interesting conclusion to be drawn from this experiment, however, is that the proportion of muscle in the increase was not greater in the bone-flour lot than in the low-phosphorus lot, No. 5, (Table XXIV, page 285), thus reinforcing our conclusions drawn from Experiment II that the phosphorus of bone is not of appreciable assistance in the formation of muscle. In both these experiments there is a slightly greater proportion of muscle in the increase with the low-phosphorus lot than with the bone-meal or bone-flour lot, but in both cases a less proportion than with the bran-extract lot.

The most noticeable effect of this low-phosphorus ration on the chemical composition of the animal was the low proportion of ash and of phosphorus to protein in the livers.

GENERAL SUMMARY

The limitations imposed by the food supply affect not only the amount, but also, within limits, the composition of the growth produced.

The mineral elements of foodstuffs appear to enter largely into the determination of their specific effects on the development of animals.

Rations of corn balanced by proteid supplements from sources other than corn, appear to be more palatable and more efficient to cause growth than rations of corn and corn products only.

The deficiencies of corn as a food for growing animals appear to be a lack of protein in proportion to non-proteid organic nutrients; a marked lack of calcium, and a less pronounced shortage of phosphorus; an excess of magnesium in proportion to calcium, and a deficiency of basic mineral elements as compared with acid mineral elements.

These deficiencies are all susceptible of correction by the use of supplements. We know of no reason why good sound corn should be entirely withheld from any animal at any time when it needs food.

The specific effects of corn as an only food, as evidenced by the growth of young swine, are in general, a retarded development of proteid and bony tissues, and an over-development of fatty tissue. This results in the production of fine-boned, poorly muscled, undersized and over-fat animals, which reach their limit of growth prematurely, and which are characterized by less than normal breeding capacity. Impaired fecundity seems to result from discouragement of proteid increase generally, and from the lessened circulation of blood in the female reproductive organs, this last being caused by pressure of the excessive amounts of internal fat which accumulate about these parts.

With hogs fed on corn alone, the bones, muscles, liver, kidneys, lungs, heart and spleen all compose an abnormally small proportion of the increase in weight, and fat composes an abnormally large part of the increase.

The muscles of corn-fed pigs are high in fat, and low in protein and in water; but the percentage of water in the fat-free meat is decidedly high. The proportion of ash to protein in the flesh of corn-fed pigs, however, is not low.

The livers of corn-fed hogs are small and low in ash and in phosphorus.

Compared with rations containing more protein, corn produces small, fat kidneys. The low-proteid corn ration makes less extensive requirements, and so produces less development of the kidneys than other rations containing more protein. This has a bearing on the feeding of growing animals. The eliminative functions of the body will not reach full development if the animal be reared on a minimum protein allowance.

The bones likewise are small, and lacking both in density, as indicated by ash content, and in breaking strength.

Corn alone as a food for swine lacks palatability. Hogs will eat very much more of mixed rations, and make much greater, more economical and almost invariably more profitable gains in weight, than from corn alone.

Corn by itself is more nearly a perfect food for maintenance than for growth. The younger the animal, or the greater the amount or proportion of protein in the increase in a given time, the less nearly is corn a perfect food for animals.

In comparing rations of corn alone with rations of corn supplemented with wheat middlings, linseed oil meal, tankage, soy beans and germ oil meal, all rations except the corn being compounded to have the same nutritive ratio, the proteid increase was, in general, in accord with the organic phosphorus content of these rations.

The development of fat was in the inverse order; that is, where the protein of the ration was accompanied by the proper mineral elements, a certain amount of proteid tissue was produced; where the protein of the food lacked the necessary mineral accompaniments, its nitrogenous portion was excreted, and the remainder used for the production of fat and energy. The tankage, linseed oil meal, and soy bean rations were about equally palatable and effective to cause gain in weight.

Tankage and linseed oil meal are about equally profitable supplements to corn at the prevailing prices of recent years.

Soy beans may be grown in the Corn Belt and used with profit in pork production, though the supply of beans on the market is sufficient only to satisfy the demands for seed, at seed prices.

Wheat middlings and germ oil meal are neither so palatable, nor so efficient, nor so profitable, as supplements to corn in pork production as are tankage and linseed oil meal.

The principal organic phosphorus compound of wheat bran, known as phytin, is a valuable nutrient. It contributes to the development of proteid tissues generally, including muscles and visceral organs, and also to the growth of bone.

Phytin was fed as a water-extract of wheat bran, the solution of the phytin being accomplished principally by the slight acidity produced by bacterial fermentation. This bran-extract is characterized by a very high magnesium content, especially so in relation to calcium. The antagonism between these elements in their effect upon the tissues renders this disproportion a matter of importance, since it exists not only in wheat bran and wheat middlings, but also in corn and in other grain feeds.

The excess of magnesium in proportion to calcium in foods appears to cause a counteractive liberation of calcium from the tissues, especially the bones, and thus we may produce malnutrition of the bones merely by the excessive use of a food characterized by disproportionate amounts of magnesium and calcium.

The ash of the bran-extract used in these experiments was, as is the ash of bran, about neutral. Hence this removal of ash from the bones was not acidosis, though the effects upon the bones was the same. Water-extract of wheat bran is a very palatable food. Its nutritive value was most pronounced when used in moderation; the pathological consequences appeared when fed in larger amounts.

"Bran disease," "shorts disease," or "miller's horse rickets" appears to be caused, in part, by the excessive proportion of magnesium to calcium in wheat bran and shorts.

The muscles of pigs which received bran-extract were characterized by a low phosphorus content, though the ration itself was rich in easily assimilable phosphorus.

The livers of pigs which received bran-extract were high in phosphorus, both in the tissue as a whole and in the ash. The kidneys from pigs which received bran-extract were low in fat and in ash, but high in water content.

Lecithin was added to a low-phosphorus basal ration in such quantity as to contribute 10 percent of the total phosphorus of the ration. This ration was compared with another in which the same quantity of phosphorus in the form of sodium phosphate was added to the basal ration.

Lecithin seems to be a valuable nutrient. The ration containing this compound appeared to be especially palatable and excelled in the rapidity and economy of the gain produced.

The muscles, livers and kidneys produced by the lecithin ration all contained a high percentage of phosphorus. Subsequent work by the author at the Ohio Station shows that phosphorus in the same condition as in lecithin contributes to the organic phosphorus content of brain and muscle.

The phosphorus of bone-meal appears not to add to the muscle-producing capacity of a low-phosphorus ration; in fact, there is some evidence to suggest that it interferes, to a slight extent, with the utilization of protein. Bone-meal, however, contributes directly and conspicuously to the ash, density and breaking strength of bone.

Bone-meal does not diminish the tendency of pigs fed on a low-phosphorus ration to make fat from the protein of the food.

The muscles of the pigs which received bone-meal were lower in ash, and percentage of phosphorus in the ash, than the muscles of pigs which had received a low-phosphorus ration lacking the bone-meal.

A ration which was very low in phosphorus, potassium and calcium, but which contained an abundance of protein and other organic nutrients, made very little increase in muscles and in bone ash.

The ration lowest in phosphorus produced muscles which were especially low in water, both in the whole tissues and in the fat-free substance; high in protein, ash and phosphorus, but low in the proportion of phosphorus to protein.

The phosphorus compounds of the food do not directly favor fattening, as they do muscular growth, but they may do so indirectly, through affecting the general health of the animal. On the other hand they are apt to discourage fattening in growing animals through making possible the normal use of the nutriment in the formation of proteid increase.

The general result of this work is to call attention to the importance of the ash constituents generally and to phosphorus in particular in the rations of growing animals.

If we are to use corn as the principal food for animals which are being fed either for growth or production of other proteid increase, such as milk and eggs, we can hope for the greatest success only by feeding with the corn, supplements that are richer in protein, calcium and phosphorus; higher in proportion of basic minerals to acid minerals, and lower in proportion of magnesium to calcium.

BULLETIN

OF THE

Ohio Agricultural Experiment Station

NUMBER 214

MARCH, 1910.

A BRIEF HANDBOOK OF THE DISEASES OF CULTIVATED PLANTS IN OHIO

By A. D. SELBY

INTRODUCTION

The idea of disease is not a simple one, though it may seem so before trying to define it. In reality the term "disease" as applied to plants, means any change in that plant toward reduced vigor, etc., from the ordinary or average behavior. To put it another way, a plant is said to be "diseased" when it shows any deviation from the ordinary or average behavior of that plant in respect to appearance, growth, color of bark, foliage, fruitfulness, time of dropping leaves or length of life; in short, when the plant fails to conform to those averages which we have established by extended observation for the species and variety in question, we say it is diseased. Under such a general definition, variegated or purple hued sports would be included, although potentially rather than actually in diminished vigor. Variegated sports succumb easily to parasitic attack and, as later investigations show, are really suffering from enzymatic troubles.

The more usual symptoms of disease are marked by evident differences in the plant. The leaves become spotted, curled or discolored, or may even drop prematurely; the fruit may develop unevenly or be marked by decayed spots, or the twigs may blight, wilt or die. In all such cases we have a manifest loss of vigor and reduced profit. Yet we may not attribute all these to parasitic fungi or to parasitic insects; purely physical or chemical agencies may be at the bottom of certain troubles. Plants may be asphyxiated by too much water which excludes the air supply; they may likewise, be strangled by escaping gases, especially in the case of city shade trees, or their protoplasm may be attacked by chemi-

cal agents such as strong acids and alkalis. Quick growing plants appear to fall in drought, as with cucumbers when started during a period of excessive rains. Plants, and especially trees, may be locally injured by winter freezing, by hail, by overbearing with exhaustion of water supply, and by a variety of causes.

While we must keep our minds open to these varying causes of impaired vigor, by far the larger number of the diseases described in this bulletin are directly attributable to parasitic fungi which attack the plant or host in some vital part and rob it of its substance. The conditions of injury arising from the attacks of insects alone are not included. These fungus parasites of particular plants are of differing sorts, which produce, each, its more or less particular effects. It must follow, therefore, that the diseases produced differ in nature and that the names applied will vary accordingly. The names are not simply blight, rust, etc., indiscriminately applied—they are given with reference both to the parasite and its effect on the host plant.*

Parasitic fungi and bacteria which cause disease, being plants, though of lower class, have differences among themselves which may be clearly designated and defined. The names applied to them are accompanied by specific and generic descriptions which mark off the sort as definitely as do the descriptions on higher plants such as ferns, flowering plants and trees. The extreme minuteness of the parts of parasitic fungi and bacteria make necessary the use of the microscope in their description and detection. The parts called spores which reproduce these minute plants have special form, size, etc., by which these are recognized when found.

The agencies for the spread of parasitic diseases are those operations in which we engage or those which surround and envelop the plants as well as ourselves. Light spores will be carried by currents of air like particles of dust. All spores or germs of these lower plants may be carried by numerous agencies such as insects, higher animals, and man. They will also find entrance into plants by whatever openings exist at the time. The epidermis of a green leaf or stem has breathing pores or stomates in it; the leaves of mustard plants have water pores in them and wounded plants have these fresh openings to invite the entrance of the disease conveying spores or germs.

The remedies for plant diseases are based upon the character and life history of the particular parasitic growth with which we have to deal and upon the nature of the host plant itself—some hosts being very different from others in respect to permitting of sprays of fungicides or insecticides. Common sense inferences are

* See naming of diseases.

always of use in dealing with plant diseases. If the soil is too wet, drain it; if late growth predisposes to winter injury, avoid such growth; if overbearing weakens plants, prevent it by thinning the fruit.

The philosophy of seed treatments is stated under diseases which infest the seed; that of soil treatments or disinfection, under soil infesting disease, and the general doctrines of sprays, fungicides, etc., under that heading further on. The progress made in plant disease prevention throughout the world during the period of about 26 years which has elapsed since the discovery of Bordeaux mixture in France shows how well adapted that discovery was to the needs of the times.

The progress made in recent years in the study and control of plant diseases has been made possible by the agencies recently developed in the United States in the Agricultural Colleges, the Agricultural Experiment Stations and the United States Department of Agriculture. It is not expected that this advance in our knowledge of the diseases of plants or of the methods of disease control will soon wane. Efforts like the present one to present briefly the doctrines of disease and the philosophy of disease control together with brief descriptions of prevailing diseases in our state, have for their purpose the wider dissemination of the body of present day knowledge in these lines. Such a statement will not close the march of progress nor make less the need for more knowledge. It is hoped that cultivators of plants, whether farmers, gardeners, horticulturists or florists will find suggestive statements of information in the bulletin by which they can direct their own efforts to better advantage and correct or broaden their own inferences from observed conditions about them. All such results will not only increase the need for more knowledge, but will furnish impetus to the movements by which we will gain the desired information.

In the preparation of the revised edition of the original Bulletin, No. 121, the general part immediately following this introduction has been considerably enlarged and brief discussions are now given concerning groups of plant diseases as well as those concerning parasitic fungi. It is fully apprehended that the host plant is the center of practical as well as economic interest and these statements concerning enzymatic diseases as in the case of peach yellows and mosaic disease of tobacco, diseases transmitted in the seed, soil infesting diseases, and the relation of the spread of certain diseases to leaf biting insects are given as aids in mastering the principles involved. The same aim has governed the discussions upon wounds

and wound fungi so especially dangerous with orchard, shade and forest trees. Somewhat fuller discussion of atmospheric agencies as affecting the occurrence and spread of plant diseases, of remedies for diseased conditions and of the application of the latter in combatting diseases and a presentation of storage troubles has also seemed desirable. Special attention is called to the host plant in the matter of breeding or selection for disease resistance and in the contrasts offered by American and European points of view in plant disease study.

ACKNOWLEDGMENTS

The illustrations in this bulletin have been drawn from wider sources than in the previous hand book. A large number, including perhaps, a larger portion of the cuts, are taken from previous publications of this Station by Weed, Miss Detmers, and the writer; small cuts have been at times made from certain larger illustrations while with others only portions of the original cut have been used.

A great many of the illustrations are new, and I am deeply indebted to Messrs. J. M. Van Hook and Thos. F. Manns for many of the photographs from which these have been made. I am also indebted to Professors Halsted of New Brunswick, N. J., and Atkinson of Ithaca, N. Y., and to the Bureau of Plant Industry of the U.S. Department of Agriculture for many favors in the matter of cuts which are used in the Bulletin. Figures 24, 25, and 26 are from Dr. Freeman's "Minnesota Plant Diseases." For permission to reproduce these, I am indebted to Prof. Frederick E. Clements, of the University of Minnesota. In all cases where it is not otherwise obvious, it has been the aim to state the source of the illustrations in the descriptions. The same applies to illustrations reproduced from standard works.

In many matters connected with recent investigations of the Department bearing upon diseases included in this present bulletin, and upon current examinations, I am under many obligations to Thos. F. Manns, Assistant Botanist, who has rendered very great assistance.

GENERAL PART I

CONCERNING PLANT DISEASES IN GENERAL

As defined in the introduction, a plant is called diseased when it fails to show normal vigor and normal condition of its parts. The manner of disease attack is extremely varied and the conditions set up as a result of disease are accordingly of many different kinds. We learn to recognize disease by the symptoms shown in the plant; these symptoms will at times be readily interpreted and on other occasions they will prove misleading. Nothing is plainer than the necessity for continuous observation of growing plants if one is to be in a position to interpret the symptoms of disease.



Fig. 1. Roots of white burley tobacco plant attacked by broom-rape. Each of these masses attached to the root shows beginning of the plant which will grow up in larger dense form, and produce an abundance of blossoms and seeds but no leaves. Each one of these must have started from a buried seed of the broom-rape, *Orobancha Ludoviciana* Nutt.

Diseased conditions may be due to the very obvious attacks of certain parasitic seed plants which lack leaf-green or chlorophyll in their tissues and must subsist on other plants somewhat after the manner of parasitic fungi. The dodders which attack the clovers, alfalfa, onions, etc., belong in the class of parasitic seed plants of the genus *Cuscuta*. Their seeds are liable to be harvested with the

seeds of clover or alfalfa and to be present in the commercial seeds. While these have been treated in the weed manual they require mention here. The seedling plant of dodder first forms a root and sends upward a whitish stem which twines about the clover or other stem, and sends sucking branches into the stem interior. These "haustoria" extract food material from the clover stem—that is they rob it of its own substance. Upon the formation of such organs the root of the dodder dies off and the future existence of these twining, strawlike stems is at the expense of the host plant.

A similar state of parasitic existence is found in the broomrape tribe whose very small seeds are scattered through the soil. Such a broomrape is well known on hemp, and the same hemp broomrape also attacks tobacco in Kentucky and possibly in our state. We have found another broomrape attacking tobacco in one district of Brown county, Ohio, and the illustration shows its appearance on the tobacco roots.

When the leaves of a plant are attacked these show the direct effects; the symptoms of parasitic leaf diseases are usually localized injury resulting in spotting and often in browning of the leaf parts. Leaves may dry up somewhat slowly and drop to the earth, and yet the leaf tissues are simply dried up. Such conditions may result from late frost as upon shade, fruit, or ornamental trees. A most interesting case was once studied upon catalpa as a result of a frost in May. In that case the drying up was none the less to be expected at that time.

An even more interesting case of leaf drying and dropping was upon young catalpa trees in a nursery caused by the attacks of a root-rot fungus, *Thielavia*. Owing to the death of many of the rootlets and finer roots as a result of the root-rot trouble, the leaves of these young trees dried up prematurely in August and September and the leaves all dropped off. Thus we may have leaf dropping as a result of frost, injury by hail, root impairment or localized parasitic attack.

LEAF SPOT AND SHOT-HOLE EFFECTS

Leaf-spot symptoms are everywhere abundant and are really of very diverse origin. In any example in which the leaf tissues are locally invaded by a parasitic fungus we may expect evident effects. In the downy mildew troubles there may be wet-rot symptoms when the weather is moist, as in the case of *Phytophthora* or late blight attacking potato or tomato leaves; after the leaves have become badly diseased they may appear to die very suddenly because

the gradual invasion of the areas has been overlooked. In many other leaf diseases no such rapid multiplication or reproduction of the parasite is possible and limited dead patches or spots are the result. The leaf-spot disease of alfalfa, the various leaf-spots of apple and the conspicuous leaf-spot of the strawberry, the beet, the pea, etc., will be recalled. In these while the leaves are impaired as to usefulness they do not perish immediately and one may readily fail to estimate the injury at its real seriousness. In a few leaf troubles we have the spotting of the leaf followed by the formation of a separation layer in the leaf tissues between the parasitized and the healthy tissues. This results in "shot holes" in the leaves as is so very conspicuous in the shot-hole leaf disease of the plum and less conspicuously so on certain sour cherry trees. These leaf troubles are commonly very evident during rainy seasons and are preventable by spraying the foliage of the diseased plants at repeated intervals, thus keeping a supply of the fungicide on the leaves to arrest renewed spore development.

An interesting leaf-spot disease of the tomato is sometimes very damaging. This disease seems to have appeared in Ohio during the memory of many close observers. Like most leaf-spot troubles which are strictly due to parasitic fungi, this tomato disease has been worst in seasons of abundant rainfall. The same applies to the shot-hole disease of the plum and the allied leaf-spot of cherry. The explanation appears to lie in more favorable conditions for spore germination and for the growth or spread of the parasitic organisms which produce the diseased conditions. Biting or sucking insects also open the way for the entrance of parasitic diseases. (See later pages.)

LEAF IMPAIRMENT THROUGH FUNGUS COVERINGS

In addition to the leaf-spots or dead areas in leaves to which reference has just been made, we have most noticeable examples of the spread of the mycelium of certain powdery mildews over the leaf surfaces. Casual observers note that these spread over the leaves and stems of roses, over the leaves of lilac, of oak, of peach, of grape, of forcinghouse cucumbers, of bean and pea and upon other plants. While the development of these fungi or powdery mildews occurs often rather late in the season, they are nevertheless damaging to the host plant over which they spread. Above and beyond the interference with the leaf action the impairment of the photosynthetic or sunlight processes of the leaves of the plants by which all real increase in substance is made to the plants, these mildews develop sucking or penetrating organs of the threads of

the mycelium. These organs called haustoria penetrate the leaf epidermis and must do this for the purpose of food extraction—it is needless to add that all food extraction from the plant acts as robbery.

Furthermore, the mildew-covered leaves drop to the ground in fall and there afford the fungus the needed conditions for the development of the resting or winter stages of its course by which it is again ready to attack the plants the following season. Because so largely external in development these powdery mildews are usually comparatively easy of control.

WILT DISEASES—SEEDLING COLLAPSE

The stems or branches of plants may suffer from localized attack by parasitic fungi as well as from hail, insect attack and mechanical agencies. The symptoms which follow will be found characteristic. In certain ones as in the clover anthracnose and in the fusarium of clover stems, we have the lesions accompanied by discolorations in which the fungus occupies a subordinate place outwardly. On the other hand the spots or *sori* of the rusts upon grains and grasses and the spots caused by the anthracnose of wheat, oats, rye, etc. show commonly a crowded occupation of the area by the parasitic fungus.

There are many examples of the effects of such lesions. Fuller discussions will be found under the description of the particular diseases. The anthracnose of the bean as well as that of the pea are good illustrations where these attack seedlings. Even clearer symptoms come out in potato rosette where the fungus parasite at early stages of growth may kill off the stem attacked, while in later attack will cause such impaired development of the plant that stem or axial lengthening is arrested and a "rosette" appearance results. A still more striking arrest of stem elongation takes place in lettuce rosette wherein the roots are destroyed so largely by the fungus in the soil. (See soil infesting diseases.)

In cankers of branches upon orchard trees the final death of the immediate branch is preceded by a depressed area invaded by the parasite.

PLANT DISEASES NOT BEYOND EXPLANATION

The old mystery attached to disease prevalence can scarcely be maintained in our day. We have worked out in recent years or had determined for us the causal relations between the ferment or parasite and the effects upon the host plant or crop. So far as we can now discover the reason for the spread of diseases, or of a

particular disease, is found in the specific disarrangements in the host plants. This discovery and announcement of these causal relations are undertaken that proper measures for the control of diseases may be finally devised and applied. We must always bear in mind that under favorable conditions plant diseases become epidemic and their rapid spread is to be expected.

The host plant, with its climatic adaptations and the parasites of our crops with their mutual adaptations to their hosts are biological factors which are capable of being influenced by prevailing atmospheric conditions. With cool, rainy weather we have brought about conditions favorable to certain parasitic diseases which will be inclined to spread while these continue. Other diseases spread under the conditions which favor them. The more rapid development of diseases of plants under these favoring circumstances is not beyond reasonable understanding; there is no mystery about it any more than in outbreaks of typhoid fever or diphtheria. By apprehending the differing conditions we may learn to separate the causal from the merely adventitious factors and thus be the better able to master the diseases which result.

While we may properly look upon infection by microscopic or other parasites as the general and usual cause of plant diseases, there are diseases of wide importance which arise from internal or physiological disarrangements in the plant. (See Enzymatic Diseases). In all cases whether of parasitic attack or of physiological disarrangement due to other causes, the host plant is weakened and predisposed to death.

GROUPS OF PARASITIC DISEASES

Parasitic diseases may be grouped in a way, according to the groups of fungi which cause them. This is helpful to the plant pathologist, though of limited practical guidance, since it requires microscopic study to determine the causal organisms. A more useful, limited grouping as is hoped, is proposed below and consists in making such groups or classes of diseases, as are descriptive of the general behavior. Such are seed infesting diseases, soil infesting diseases, root diseases, diseases of foliage, wound troubles, timber rots, etc. The great mass of diseases are treated under each host in the descriptive portion arranged alphabetically. The objects to be attained by this method of arrangement are obvious and call for no discussion.

NAMING PLANT DISEASES

Plant diseases are named with due regard to the symptoms and cause of the disease. In the case of enzymatic diseases wherein we have peculiar variations or yellowing of the leaves, the names given are more or less descriptive. The same applies to the diseases that are caused by freezing, hail, etc.

Parasitic diseases are named with regard to the organisms which cause the disease, or to the effects they produce in the host parts, that is, those diseases which result from attacks of the rust fungi, (*Uredineae*), are properly called rusts; also the smutty, dirty conditions resulting from the attacks of the smut fungi, (*Ustilagineae*), are known everywhere as smuts; these are well known and destructive upon grasses and cereals. Thus we have smuts of oats, corn, wheat, broom corn, sorghum, millet, blue-grass, etc.



Fig. 2. Head or panicle of oats destroyed by loose smut. All the oat kernels and many of their surrounding parts have been converted into black, sooty (smutty) masses by the loose smut fungus, *Ustilago*.

The anthracnoses are produced by a definite class of fungi, (*Melanconiae*). The name anthracnose is applied to a disease of a given host caused by an organism of this group and the host name is usually retained, as the anthracnose of wheat, the anthracnose of rye, the anthracnose of raspberry, wherein the diseases are caused by species of this group of parasitic fungi. However, in the case of attack upon the fruit as in the anthracnose of apple, because of the bitter taste given to the fruit, we have the popular name bitter-rot; in a similar instance, viz., that of the anthracnose of the grapeberry, the discolorations of fruit are so characteristic that it is popularly called the birds-eye rot. With wheat, oats, rye, etc, the name is applied because of the organisms found. As stated in the preceding pages, we describe most leaf infesting diseases with regard to the effects the parasites have upon the host; thus we have the leaf-spot disease resulting from attacks of any one of a number of fungi, chiefly, however, belonging to the imperfect forms. The shot-hole fungus of the plum is a good illustration of the naming of a trouble from the symptoms produced.



Fig. 3. Section through an anthracnose spot (*acervulus*) of the cucumber anthracnose fungus (*Colletotrichum lagenarium*) showing the long, dark hairs (*setae*) of whose office we know little, the spore bearing branches (*fertile hyphae*) and the spores of this fungus. The members of that division of the commoner anthracnoses having setae in the acervuli are referred to the genus *Colletotrichum*, while similar ones without setae bear the genus names *Gloeosporium*, *Sphaceloma*, etc. (See anthracnoses of apple, grape, lettuce, wheat, oats, etc).

A considerable group of diseases are known as downy mildews. Among these we have the destructive potato late blight and rot, *Phytophthora*; also the cucumber disease, *Plasmopara*, as well as the

grape downy mildew and the common white molds of the mustard family. The powdery mildews by reason of the appearance upon the surface of parts attacked, are descriptively named "mildews." A definite system has been followed in most cases of naming plant diseases and I trust the results will not be altogether disappointing.

The differences between the species of parasitic or other fungi are as strongly marked as those of higher plants, even though microscopic examination is necessary to distinguish these characters; it shows, therefore, that a discriminative system of naming diseases has a secure foundation.

THE PLANT OR HOST IN RELATION TO DISEASE

As stated elsewhere only closely related plants are usually subject to attack by a parasitic organism, thus it happens that the tomato as well as the potato plants are attacked by the downy mildew or late blight fungus of the potato. In general the true parasites among our fungi are limited to a rather narrow range of host plants; thus we may expect the potato *Phytophthora* to attack several plants of the potato family (*Solanaceae*). The writer proved this same was true of the attacks of downy mildew (*Plasmopara*) upon a number of species belonging to the cucumber family (*Curcubitaceae*). Since our cereal grains belong to the same great family as the grasses (*Gramineae*), we expect, and find that there is a development of the same diseases upon many of them and upon the grasses growing nearby. In this connection it must be remembered that clover and alfalfa are not grasses, but legumes.

The leaves of the host plant provided as they are with stomates or breathing pores, minute openings through the epidermal covering of the leaf, will be attacked through these openings. The spores

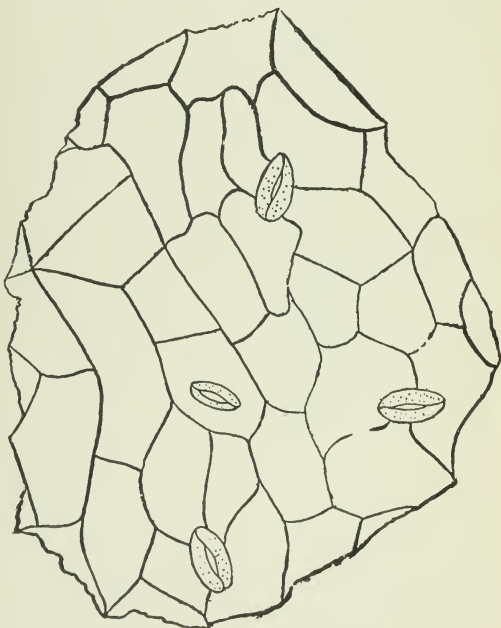


Fig. 4. A portion of the epidermis from the upper surface of a cucumber leaf, showing the breathing pores (stomates) surrounded by guard cells containing chlorophyll grains, much magnified. These guard cells, which control the opening and closing of the stomates, are the only epidermal cells that contain this green substance, the others being colorless.

of parasitic fungi after germinating upon the leaf will likely gain entrance into the interior leaf tissues through these openings much more readily than by actual boring through the leaf epidermis.

The illustration, Fig. 4, shows how these openings are distributed in the epidermis of a cucumber leaf. These stomates are present in the leaf covering upon the outside of all green leaves and in the epidermis of young growing shoots. In addition to these stomates

certain classes of plants such as the plants of the mustard family (*Cruciferae*), as cabbage, cauliflower, turnip, also the grape, fuchsia, impatiens, etc., are provided with water pores—marginal openings through which the excess water of the plants is excreted. These water solutions of various materials offer a means of growth for organisms, especially of the minuter forms. From the culture drops thus formed the parasite enters the leaf by the water pores. One of the most destructive known diseases of plants is the black-rot of cabbage, cauliflower, turnip, ruta-baga, etc. This is due to a bacterium which gains entrance very largely through the water pores just described. So we must bear in mind that the very avenues of transpiration or excretion, so essential to plant growth, are made a means of exposing the plant to the danger of parasitic invasion. This is analogous to the exposure of human subject to diseases of the respiratory organs. At every turn we find convincing evidences of the mutual adaptation of parasitic fungi to their host plants, in nothing more strongly marked than in the limitation of the species of plants attacked by a given parasite as discussed in the beginning of this paragraph. In view of the fact that so long as the leaves of a plant continue to function as leaves, these natural openings will



Fig. 5. Margin of cabbage leaf showing excreted water from water pores after cool night. These drops contain enough food for the growth of the black rot bacteria. The motile forms may swim through the water pores into leaf from such drops. Dead marginal areas on lower fragment show results of this bacterial infection. (After Smith).

be maintained, it will be seen that the risk of exterior infection from parasitic fungi is continuous for any given plant; it lasts for its whole growing period.

THE PLANT'S PROTECTION AGAINST PARASITES

In the case of woody growths we have the development of corky epidermis or bark which seems primarily designed to protect the interior, living layer from invasions of this sort. In a similar

manner the external layer or bark of all growing plants, including herbs, is provided with a protective covering or epidermis. The skin of the apple or of the grape and the covering of the potato stem are all familiar and serve this function of protection to the inner tissues. In young plants there is retained the power of protective growth in response or resistance to parasitic attack; thus it happens that the potato scab organism induces the growth of cork cells on the outside of the potato and makes a roughness. The roughness is not the scab fungus but the corky growth of the tubers in response to the scab attack. In a similar manner the attack of the scab fungus upon the apple results in the roughening of the apple skin through the development of more protective or wound cork. The most remarkable example of this multiplication of protecting or outer cells in response to the attacks of parasitic fungi is found in "leaf-curl" of the peach and in the pockets or "bladders" of the plum, where we have such a rapid multiplication of cells in response to the stimulus of the fungus as to bring about an entire transformation in the form and structure of the parts. While we may think of this abnormal development as the result of fungous growth, it is only indirectly so. It is in fact a response of the host to the stimulus of the invading fungus. The nature of the stimulus or excitation exerted by particular parasitic fungi is a highly interesting subject for investigation.

DISEASE RESISTANCE IN PLANTS

Disease resistance and disease susceptibility are as yet imperfectly understood. The cause of the inherent differences in the tendency of this or that variety to suffer, as with the leaf-curl in the Elberta variety of peach, the apple scab predisposition in White Pippin, Winesap and others, may become in practice, varietal weaknesses. Yet such is the commercial superiority of some such varieties that they increase in public favor despite these weaknesses. The great differences among varieties of fruit in susceptibility to the diseases which prevail under certain conditions, is a matter of observation and experience. From the difficulties involved in breeding a less susceptible or more resistant type of tree fruit belonging to any commercial variety, increased resistance is not yet within reach. This applies to established varieties and yet leaves the field open for new sports to be discovered or for its occupation by less desirable sorts which do not suffer so severely from disease. This actually happens in the growing of pears outside of certain favored districts; owing to the ravages of fire blight, a bacterial disease, the ordinary grower selects less popular but more resistant varieties for culture.

In the study of disease susceptibility it has been shown that other features being the same, the percentage of water is an index: thus, parts having the higher water content are attacked more readily than those with lower water content.

With annual plants or those reproduced each year by tubers or seed, the opportunities to breed resistant strains are extremely good and the results obtained are highly promising. Physiological weakness in plants may often be translated in terms of disease susceptibility; this holds with emphasis in vegetables and grains. Apparent physiological vigor may arise from various causes, and when expressed in terms of more rapid growth or higher water content or succulence of the parts may be indeed a source of weakness in the midst of disease. Selections made for the purpose of securing resistance to disease are made under conditions of *disease prevalence* with highest promise. This field of breeding for disease resistance is one of fruitful promise.

Studies in this line have been made by the Horticultural Department of the Station in respect to resistance of potato plants to the early blight disease. By selection of hills that withstood early blight attack and planting tubers therefrom and subsequent repetition of this work (See Bulletin 174) early blight resistant strains were secured. The differences between these strains and non-selected tubers in 1908 during the marked prevalence of early blight was very striking and clearly showed that a tangible resistance capable of reproduction has been secured. Owing to the wide extent of this field with vegetables and grains, much may properly be expected from breeding for disease resistance in the future. Much progress has been made with cotton resistant to wilt and with musk melons resistant to leaf blight. For the present other remedial measures will also need to be pushed.

CONCERNING PARASITIC FUNGI

A fungus (plural, fungi) is a plant, a member of the class called fungi. The fungi are low in the scale of plant life, being classed with the algæ and other similar plant forms. They are lower still in the life scale than the mosses and liverworts; above the mosses come the fern-plants, and above these the seed plants, such as grasses, grains, clovers, trees, shrubs, herbs and the like, with which we come in contact every day. The fungi are distinguished from higher plants as well as from their nearer relatives, the algæ, by the absence of green color, and for that reason, we may assume, by the lack of power to prepare their own food from the mineral substances dissolved in water, and from the gases contained in the atmosphere.

Herein they are marked off from most groups of plants: the fungi must live upon the substance of living or dead plants or animals. If they ever possessed the power of utilizing the same foods as most other plants, this ability has been lost. Parasitism is usually taken to indicate degeneracy in character. One way of regarding the fungi is as algæ without chlorophyll, to which the latter owe their green color. As above stated, the fungi are, in the absence of chlorophyll, forced to live upon the dead remains of plants or animals, or to prey upon the living organisms.

CLASSES OF FUNGI

Such fungi as subsist upon living plants or animals are called parasitic fungi. A parasite is one who eats at another's table and the adjective "parasitic" comes from this word, parasite. It is the parasitic fungi especially of which we must learn, since this class produce diseases when they attack other plants. The plant attacked is the "host" plant, however unwilling the entertainment of the sycophant.

Most fungi are very minute in size and require the use of a microscope to study their parts; certain ones, however, such as the mold upon bread or other foods, may be seen very easily to consist of fine, thread-like growths interwoven together, and bearing certain rounded parts upon erect branches. Some idea of fungus-structure

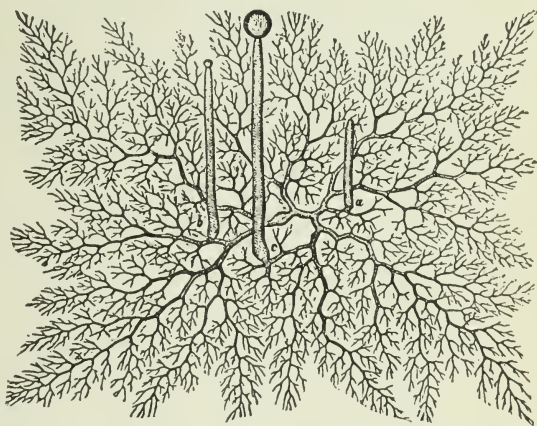


Fig. 6. Mycelium of the common mold (*Mucor Mucedo*). From the spore lying near the middle of the figure, and strongly swollen, one sees the thick threads of the mycelium arise; these in turn become richly branched. There are no divisions in the mycelium. From the level of the mycelium arise three vertical fertile hypae, *a*, *b*, *c*, of which *a* is still very young and that at *b* is already producing a sporangium containing many spores. All highly magnified. (After Zopf, from Reinke).

may be obtained by studying these common molds; that on a discarded melon rind will show the parts above described, and by the use of a microscope we may learn that the rounded, ball-like enlargements just mentioned consist chiefly of small bodies that are capable of growing into other fungus-threads. (Fig. 6). Such minute parts capable of germinating and again producing the fungus are called spores. Most spores are very minute and are not heavier

than the other dust particles carried by the wind. The spores of fungi are the means by which these are most commonly reproduced,

somewhat after the manner that the higher plants about us are reproduced by their seeds.

While we have cited the bread mold as a good illustration to show the structure of a fungus, it is not a parasitic fungus; a mold or like growth which



Fig. 7. 7a. A portion of leaf of pea showing breathing pores and parasitized by powdery mildew; the horizontal threads (*sterile hyphae*) and summer spore bearing parts of the mildew fungus (*fertile hyphae*) are distinctly shown. In these latter the septa are evident. 7b. A spore sac (*ascus*) of the same fungus. 4, 5, 6, show the sucking organs (*haustoria*) of the sterile hyphae of this fungus; these penetrate the epidermis of the leaf. 10 shows the spores of the rose mildew germinating. All highly magnified. (After Tulasne).

Note—The stomate in foreground is distorted. See Fig. 2.

lives upon decaying material is called a saprophytic fungus. To this same belong the mushrooms or toadstools that may be found in manure piles, in the woods and in orchards; the fact that we find them in such places shows that there is decaying organic substance at that point, upon which these plants may subsist. A like condition is found in the shelf-fungi on old logs and stumps, on the under surface of which we may write our names. Yet if we will use a hand lens we may often discover this under surface to be but a network filled with small openings or pores from which the spores of the fungus will in time escape. In like measure the spores of mushrooms are found in similar canals or upon the sides of the gills beneath the cap of this sort of fungus. The bacteria, or fission fungi, are one-celled plants multiplying by division and by spore production; with bacteria evident mycelium is lacking and they are structurally lower in the scale of plant life than fungi provided with a mycelium. Bacteria are both parasitic and saprophytic. But to return to parasitic fungi:



Fig. 8. Fertile hyphae (*conidiophores*) of the downy mildew fungus on *Cardamine*, a mustard protruding from a stomate; the one shown in full, bearing spores at the end of its branches. Highly magnified. Very similar to this are the downy mildews of grape, cucumber, lettuce and some others. (After Zopf).

PARTICULAR FACTS ABOUT PARASITIC FUNGI

Like the bread mold, or the other fungi just mentioned, parasitic fungi consist of a growth of threads or hyphae (singular, hypha) which do the necessary work of getting food for the parasite; these also in due time give out certain branches destined to bear spores, somewhat after the manner that the pear tree has flower clusters, or the wheat plant forms its dense spike of bloom, both of which are especially designed to produce seeds from which wheat plant and pear tree may in turn be grown. The essential parts of a parasitic fungus are these threads, or hyphae, and the spores produced by them. The hyphae of the fungus taken collectively are called the mycelium, which consists of threads that produce no spores (sterile hyphae) and of those destined for spore production (fertile hyphae. (Figure 7). It is to the food getting qualities of the hyphae that the fungus owes its continual existence, and they in turn arise from a spore or directly by the growth of some fragment of fungus-thread, as the Carolina poplar may be grown from a cutting. Yet, while all parasitic fungi are made up of these few parts, the differences in form and apparent structure among the several groups are very marked; differences exist as to the thickness of the hyphae whether or not the threads are divided into separate cells by divisions like those at the joints of a bamboo rod, as well as in the manner of spore formation and in the size, color, form markings and structure of the spores themselves. It is almost hopeless to undertake to illustrate types of spore production and spore forms, since these are so varied and may differ so much at different stages of the development of a single given species of fungus, yet we may cite a few examples:

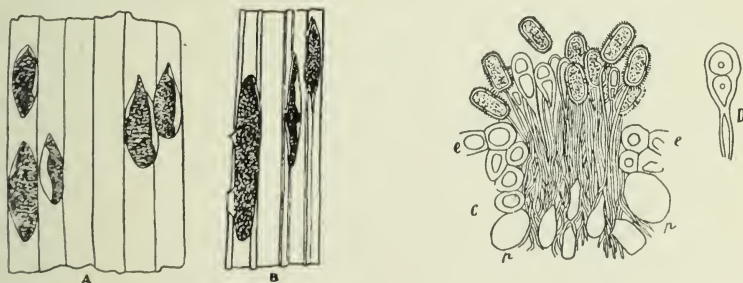


Fig. 9. Showing the common rust of oats and rye. At *A* a small fragment of rye leaf with several orange-red, rust sori breaking through the epidermis; these are of the earlier summer spores (*Uredo*) or red rust of popular speech. At *B* a small fragment of a rye leaf with several black, rust sori, elongated in form, breaking through the external covering; these are of the later summer or winter spores (*Teleutospores*). *A* and *B* slightly magnified. At *C* section through the uredosorus of *A*; on the slender stalks (*basidia*) the rough one-celled uredo spores, and between them a young, two-celled teliospore, which later alone form the sorus. *e*, *e*, epidermal cells; *f*, *f*, cells of the leaf interior through which runs the mycelium of the fungus. At *D* a teliospore from the black sorus of *B*; this is divided by a septum into two cells. Similar uredosporos are found in most rusts; similar teleutospores occur in corn rust, wheat rust, etc., and in the spores of the cedar apple fungus. *C* and *D* considerably magnified. (After Zoof. from Frankl).

Fungus spores may be produced as single spores or in naked clusters attached to certain branches. We find this sort in the downy mildew of the cucumber and its relative the peronospora of mustards (Fig. 8); in potato early blight; in fruit rot of plum, cherry, peach, etc., and later in the spores of apple scab. They may also be found in dense clusters breaking through the skin of the plant like the many tubers of a potato breaking through the earth-crust; such without further conspicuous covering are found in the rust spots, in the anthracnoses and the like. (Figs. 3 and 9). These dense clusters may arise beneath a special covering resembling nothing so much as the traditional beehive, but are usually ejected forcibly from a specially provided opening at the top of the cone or half-ball. (Fig. 10). A yet more interesting class is that in which the spores are

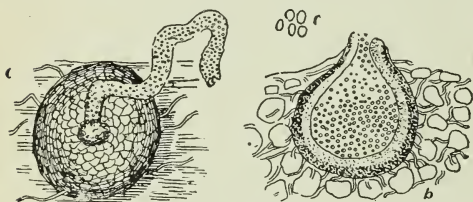


Fig. 10. *a*, spore case (*pycnidium*) of a beet leaf-spot fungus (*Phoma*) seen from above and showing the slender, flexuous mass of spores, ejected from the pycnidium. *b*, section of a pycnidium, seated in the leaf tissues and filled with spores. *c*, a group of the spores. All highly magnified. (After Allescher from Delacroix).

packed so many to a sac (usually eight) and a large number of these crowded into a ball-like, hollow spore-case, such as we find in black-knot, strawberry leaf-spot, the powdery mildews and in some other instances. (Fig. 11). There is yet another sort in which the spore sacs are abundant near the surface of the diseased part, as in leaf-curl of the peach, where the maturity of the fungus is shown by the change in color of the affected leaf surfaces. Other gradations will be found as one proceeds in this study.

THE SURVIVAL OF PARASITIC FUNGI

Further, respecting parasitic fungi we must realize that they are all derived by specific processes of reproduction peculiar to the fungus in question; in other words spontaneous generation does not find support among the students of plant diseases.

The presence of any given fungus leads us at once to infer the previous existence, somewhere within reach, of a fungus of like species from which this one was derived by definite methods of reproduction. Likewise, the destructive prevalence of a parasitic fungus in any given time and at any given place, assures us of the necessary supply of spores to start the trouble again under favorable conditions. In fact, all our study leads us to look through mere phenomena, mere evidences of disease, to find the specific parasitic growth which causes them and the favoring conditions under which

these develop. The spores of fungi serve for them the same purpose as do the seeds in higher plants; by reason of the extreme smallness of the spores they are easily transported by the wind and become deposited like dust particles upon exposed surfaces. Certain resting spores survive on the fallen leaves or other parts and will be destroyed if these parts are burned. (See black-knot). The survival of organisms capable of infecting the new crop is certainly to be expected in plant diseases as in epidemic disorders among people.

Some fungi which produce disease survive by their thread-like parts (*mycelium*) in a manner similar to the survival of Canada thistle quack-grass and the mints among troublesome weeds by their visible underground stems. A good illustration of this form of survival is found in the case of potato rosette; in this disease the masses of mycelium (*sclerotia*) remain upon the surface of the potato tubers and unless destroyed by treatment of the seed will be ready for immediate attack upon the growing plants (sprouts), even before these have reached the outer air and taken on a green color.

Similar survival may occur in cultivated soils, especially where the same or closely allied crops are grown in succession. Thus the same fungus as that of the potato disease first named, survives in greenhouse soils or in celery soils outdoors.

RESTING FORMS AMONG FUNGI

The active parasitic phases of fungi necessarily coincide with the activity of the host plants; it, therefore, follows in our temperate climates with alternating periods of activity and rest of growth and practical somnolence, that the parasites require to be mutually adapted to intermittent activity. Some spores will survive the brief rest period between harvest and seed time, as in a number of the various grain smuts and in grain anthracnoses. Here they are found simply adherent to the seed grain.

Seed infesting parasites like the loose smut of wheat, the anthracnose of pea and bean, and a variety of other vigorous species survive as resting mycelium, which remains virtually inactive so long as the parasitized seed is not exposed to conditions of moisture and temperature such as bring about germination.

There are endless gradations between these instances of "resting" mycelium and the protected fruit cases of the higher type of fungi. Thus the perithecia or closed fruit bodies of the wheat scab fungus, develop shortly after harvest upon the infected glumes or culms of wheat, and may be observed by the unaided eye, as black bodies seated upon the pink mass of the summer form. These fruit bodies in this case are the kind called "perithecia," which contain

within them spore-sacs of a nearly fixed number and each sac contains a fixed number of spores of definite form for each species. A great many fungi develop these "housed" or protected forms during the dormant period, and indeed, spore development may proceed in the periods of lower temperature.

With the perithecial or sporehouse form of wheat scab, (*Gibberella*), the spore sacs are formed during the later summer, in our latitude, and these spore sacs disappear before midwinter. For each genus or species under study, peculiar time relations of development may be discovered. The perithecial or spore sac (*ascigerous*) form just described, or some comparable development of the spores under

a definite cover-form, is viewed as a more or less ultimate stage in the development of the higher fungi—the summit in the cycle of their development.

The rot of stone fruits, such as peach, plum, cherry and the like, is commonly known only in its conidial development called *Botrytis*. Recently Norton has discovered the *Sclerotinia* or ascigerous stage developed from the mummy fruits in which the fungus lay dormant for a

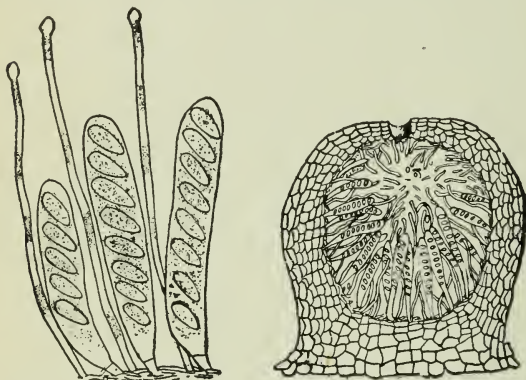


Fig. 11. Section through a spore case (*perithecium*), late winter stage of black-knot fungus, showing spore sacs (*asci*) within. Beside it, three asci containing winter spores or ascospores, eight in each sac, arranged in a definite manner. Along with these are thread-like hyphae known as paraphyses

time awaiting spring or summer conditions.

The bitter-rot of apple and its cycle of development not long since brought to light in Illinois, also shows the relation of the apple mummies, decayed by attacks of this anthracnose, to its survival. The fungus lives over in the old rotted fruits, acted upon by bitter-rot alone, which hang upon the trees. The fungus may also survive in branch cankers upon the tree adjacent to mummies of the bitter-rot. In these branch cankers the spore sac or perithecial stage of the fungus is developed. Upon the coming of warm showery weather about early June, new spores are produced from either mummies or cankers and new infection may occur upon the new fruits. The problem of the control of this disease, therefore involves a knowledge of its manner of survival.

ALTERNATION OF HOSTS IN FUNGUS SURVIVAL

This relation of alternating forms in the life cycle of a given parasitic species, to its survival, has been mentioned in wheat scab wherein we have the *Fusarium* or pink mold and the *Gibberella* forms; in rot of stone fruit where we find *Botrytis* and *Sclerotinia* forms, and in apple anthracnose or bitter-rot where we discover the *Gloeosporium* followed by the *Glomorella* ascospores. In these instances there seems no real need for the advent of another host plant. In other groups of fungi, notably among the *Uredineae* or rusts, we discover in certain species, that survival is accompanied by a necessary change of host plant. The apple rust is known in summer to attack the leaves and fruit of apple, thorn apple (*Crataegus*), june-berry and mountain ash. This is the aecidial or cluster-cup stage of the apple rust and has its counterpart in the aecidiospores or cluster-cups of the wheat rust upon barberry as well. With apple rust we climb far on the plant ladder and find the teleutospores of rust survive upon the cedar trees as branch enlargements called cedar apples (*Gymnosporangium*). The dry looking apples upon the cedar trees take on a new form during spring showers when they become great, jelly-like masses which emit the teleutospores of the rust, to be carried to apple, juneberry and crataegus leaves by whatever agency is available.

The relation of cedar trees to the prevalence of apple rust is a practical matter for each orchardist. It may be better to make firewood of the cedar trees than to combat the apple rust in his orchards. A similar problem as between the barberry hedges which adorn rural England, and the virulence of wheat rust in their grain fields, may also be raised. With us we have plenty of grain rust in the absence of barberry hedges. An adaptive form of survival apparently takes the place of the alternating hosts, and we still have the wheat rust.

The instances given are simply illustrative and the student of plant pathology will discover many more in the course of his study. Likewise a careful perusal of the special part of this bulletin will show other instances of survival under many various and instructive conditions.

HOW THESE PARASITES ROB THE HOSTS

There is an old saying about the stable door and the stolen horse; similar application may be made for plants and parasitic fungi in a manner which we shall presently perceive. To obtain food we must reach the source of supply; the manner of reaching it is less important than the result. Now it occurs that cultivated and wild

plants of the higher classes are wrapped about by a covering of skin or bark, and the food-filled juices are within; to feed upon any living host the parasite must gain access to the internal tissues of that host. It so happens that there are minute openings or stomates (breathing pores) through the skin of leaves and of young green stems; these openings are as necessary as the stable door, and through them the thief may enter. (See Fig 4). Were these openings to become entirely closed the plant would languish, and remaining open, they constantly offer a way for the tender tip of the growing germ thread of a fungus to push its way through the plant covering and to luxuriate within the host upon the substance of the plant. Once within, the fungus thrives, rapidly multiplies its

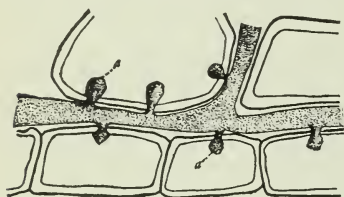


Fig. 12. Haustoria of the fungus of the grape downy mildew penetrating cells of grape stem. The shaded portion shows the mycelium of the fungus growing between the cells, sending haustoria, *aa*, into the interior of the cells. (After Scribner from Farlow).

Note: In this figure the lower row of cells have the form of empty epidermal cells in which the fungus would find little to subsist upon. Farlow's original figure does not give these cells such form.

branches, and if in summer, commonly thrusts its fertile threads through some of these breathing pores to bear its spores outside where they may become more widely distributed than if remaining within the tissues of the host plant. Should, however, the winter season be near, resting spores may be formed, or their formation be provided for within the leaves, or diseased parts, as in grape downy mildew, elm-leaf disease and in black-knot of plum and cherry. Thus the cycle of development continues indefinitely unless some agency intervene to destroy the spores, to prevent their germination, or the parasite itself so exhaust the host plant as to destroy it entirely and the fungus perish for lack of suitable nidus. However, this rarely occurs, not perhaps, so often as men are guilty of killing the goose which lays the golden egg. Herein, we meet another fact, namely, that parasitic fungi of a given kind are limited to a particular host plant of a certain species, or to a small number of related plants, so that if a congenial host is lacking the fungus will not thrive.

The fungus threads growing within any plant will not flourish if simply passing between the cells of the host; penetrating organs pierce the cell walls and are able to absorb nutriment from the cell interior. (Fig. 12). The diverse forms of sucking organs, and the peculiar structures of fungus threads in these situations would in themselves require much study and investigation to present them properly. We must further conceive that a fungus may often

branches, and if in summer, commonly thrusts its fertile threads through some of these breathing pores to bear its spores outside where they may become more widely distributed than if remaining within the tissues of the host plant. Should, however, the winter season be near, resting spores may be formed, or their formation be provided for within the leaves, or diseased parts, as in grape downy mildew, elm-leaf disease and in black-knot of plum and cherry. Thus the cycle of development continues indefinitely unless some agency intervene to destroy the spores, to prevent their

penetrate the bark of a tree for example, if aided by rifts caused by freezing or similar disturbances, to say nothing of the openings offered by wounds, the breaking of branches, etc. A recent illustration of the danger of rifts in the bark of trees is offered by the chestnut disease which is proving so destructive near New York City. Few parasitic fungi have that penetrating power of thrusting the haustoria through the plant covering such as we find in the case of the dodder that twines about and robs the wild herbs and shrubs of the woods and fields as well as the cultivated flax and clovers.

HOW PARASITIC FUNGI AFFECT THE HOST

We know the cumulative effects of insufficient food supply; these effects must hold for plants attacked by parasitic fungi. Aside from the nutriment diverted to the parasite, there is reduced functional vigor of leaf, stem or root, and the loss becomes increased in this way. Let all the leaves be parasitized, or let even three-fourths of them be entirely so attacked, and we may look for great loss of foliage, possibly entire loss of fruit and the detailed effects of diminished vigor, unripened wood, or by repetition, entire destruction of the host. Usually the effects are of many gradations, but in all cases of leaf parasites the entire plant must suffer. We have learned that bacteria may, in a suitable medium, destroy themselves by the formation or emission of poisonous products which are fatal alike to the bacteria and to animals, or even man; that such takes place within plants parasitized by fungi remains in doubt, and may be disregarded for the present. The results of impaired function in the parts are serious enough to demand our attention. It is altogether probable that future investigations will modify our views upon some points.

There are many curious transformations and malformations resulting from the attacks of parasitic fungi, simply by the multiplication of cells of wound cork or other tissues in the effort of the host to shut off the fungus, not because the fungus consists of such a mass of tissues. (See leaf-curl of peach).

While exceedingly interesting to trace the effects of the white mold on shepherd's purse and on the garden purslane, as well as the effects of bramble rust, cabbage club-root and a number of others, the principle above pointed out will be found generally applicable, and it is to the reactions of the host plant that the excrescences or malformations are chiefly attributable.

It may further be stated that artificial cultures of parasitic fungi, either upon culture media or living plants are constantly adding to our knowledge in these lines.

BENEFICIAL ORGANISMS: ROOT NODULES, ETC.

While realizing the losses caused by parasitic fungi and bacteria we may not hastily condemn all fungi and bacteria. One of the most profound influences of aging culture of the soil is the beneficial

effects in nitrogen fixing, exerted by the root nodule bacteria of leguminous plants. The well known beneficial effects of the root nodule bacterium upon clover has made rotation in clover an agricultural necessity. The species or forms of root nodule bacteria required on alfalfa, cowpeas, vetches, etc., have become recognized as factors of consequence in our efforts at seeding and new species of legumes on the farm.

A less understood relation between certain fungi which develop as mycorrhiza upon the roots of some deciduous trees and notably on conifers may not be passed. Herein we may find an explanation of rotation in forest species when reforestation crops are to be grown.

THE PROOF OF PARASITIC CAUSE IN PLANT DISEASE

The mere presence of a fungus, determined by the microscope in diseased tissues of the plant, does not prove the case against the organism found. It is not easy at all times to be certain whether discovered spores belong to this or that organism, or group of organisms, although with certain groups as the anthracnoses, species of *Fusarium*, etc, the spore forms give somewhat clear evidence. The differences between parasitic and saprophytic fungi are not always simple matters admitting of ready determination; further, we must bear in mind that after a parasite has caused death or even minor lesions in a plant, the organisms of decay may be expected to appear to do their great work as the scavengers of the world. The fungi or bacteria found in a dying plant may be both saprophytic and parasitic, or these may be only saprophytic.

The methods of proof of parasitic cause in the bacterial diseases of animals including man have been extended to the study of bacterial diseases of plants and finally to the diseases caused by parasitic fungi. These methods consist of a group of rigorous exact rules which are stated by Dr. E. F. Smith in the following terms:

- (a) Constant association of the organism with the disease.
- (b) Isolation of the organism from the diseased tissues and careful study of the same in pure cultures on various media.
- (c) Production of the characteristic signs and lesions of the disease by inoculations from pure cultures into healthy plants.
- (d) Discovery of the organism in the inoculated, diseased plants, re-isolation of the same, and growth on various media until it is determined beyond doubt that the bacteria in question are identical with the organism which was inoculated.

While these methods and rules are stated with special reference to bacteria as the cause of disease, they apply with equal force to the proof of cause in the case of any given parasitic fungus. These methods require rigorous and exact work in the isolation and subsequent culture of the parasite upon sterile media, followed by equally careful inoculation work using these pure cultures as a source of the organism.

METHOD OF INOCULATION FROM CULTURES

The methods of inoculation tried by the investigator are of great importance. These determine, in fact, the success or non-success of his efforts. There must be adaptation of the method to the life history of the parasite and the developmental stages of the host plant, including the appearance of the parts more commonly attacked by it.



Fig. 13. This shows method of infecting field plots by means of the hand spray pump, using the washings of samples of wheat and other grains. The washing of grain containing spores of disease such as anthracnose or scab may be used. Cultures may also be sprayed upon plants in this way or by means of blow-bottle in smaller tests. (From Bul. 203, Ohio Experiment Station).

Following the methods of earlier bacteriologists, needle pricks are often employed both in the inoculation of fungi and bacteria into plants. One seeking to pursue a special line of inoculations will need in all cases to study his conditions as well as the methods of other investigators. Thus, doubtless, inoculations like those of *Phytophthora* and *Plasmopara* may be best attained by using drops of sterile water to carry the spores. The same principle applies in field

methods upon many crops. In the case of grain diseases, notably anthracnose and scab upon wheat, rye, oats and grasses, inoculations may be made by spraying the cultures upon the grain at a proper stage of its development.

While some groups of fungi do not lend themselves readily to culture upon the usual media, it is the aim of plant pathology to make this possible with a constantly increasing number of these parasites.

CULTURE PROOF NOT ALWAYS POSSIBLE

While in all cases of bacterial diseases where the body of the organism is so little different from that of the bacteria of decay, fermentation, etc., these rigorous proofs are required before the disease is listed as of proven bacterial origin, we do not find it necessary in practice to reprove again the case as against frequently occurring species of fungi associated with particular plant diseases. This does not make it less necessary to prove all cases as to parasitic cause, although the practicability in any single laboratory of pathology is admittedly one of narrow limits.

ENZYMATIC DISEASES OF PLANTS: CHLOROSIS OR PANACHURE

To this form of physiological breakdown, induced however, by specific causes recently determined, we attribute some very widespread and injurious diseases which belong under the head of chlorosis. Peach yellows, possibly peach rosette, frenching or mosaic disease in tobacco, and in general variegated or special yellow foliage types of plants as in *Arundo*, *Acer* and other genera of plants belong here. The yellows in peach has long been studied, as also the tobacco mosaic disease. In yellows the contagious character of the disease and its transmission in pruning by contact of parts of the harness of team and by or through the atmosphere has been recorded.

A few years ago it was determined by Beierjink and by Hunger that this infection exists as a chemical compound or compounds of complex nature belonging to the oxidizing ferments of a group called the oxidases. Oxidase, peroxidase and others of these ferments are known. They act by breaking down or oxidizing the plant leaf tissues and especially the chlorophyll or leaf-green of foliage and young tissues, converting it into xanthophyll. The tests for these ferments are of some importance. Woods and others have shown their action with peroxid of hydrogen.

From a practical point of view the transmission of the ferments, and, therefore, of the disease, by touching first diseased and then healthy foliage is rather surprising. The work of Hunger in Java

upon the transmission of the tobacco mosaic disease makes the risk of transmission from diseased to healthy plants by such handling, stand out clearly. This line of transmission was verified on tobacco by the writer's assistant in 1903 (See Bulletin 156, of this Station).

While the same class of proof for peach yellows is very difficult, owing to the latent nature of the disease for some months after first infection, the actual results of infection from nearby diseased trees make clear the danger of such exposure and the necessity for the destruction of diseased trees. Chemical examination of variegated or chlorose tissues shows the same compounds, the oxidases, etc., to be present and to account for the transformation of the leaf-green or chlorophyll, into xanthophyll, or leaf yellow. Thus by degrees apparent plant disease mysteries are solved. The weakness of variegated plants and their ready susceptibility to attacks of parasitic fungi are now explained by this impaired condition of the leaf parts.

PLANT DISEASES TRANSMITTED IN THE SEED

The public in general little realizes how many diseases of plants are transmitted in the seed, although as the years pass the general dissemination of knowledge concerning infection by spores and by germs has partly prepared the way. The public mind does not longer expect something to grow from nothing. The treatment of seed grain, as wheat, oats, barley, etc., to destroy adhering spores of the smut fungi, and thus prevent these smuts in the crop, has been known for many years. In the early days of the Agricultural Experiment Stations, these doctrines and practices in this regard were widely disseminated, new impetus being given by the successful use of hot water following the methods of Jensen in Denmark; but despite the conquest of the practical control over the order Ustilagineae, the smuts, we have only really begun to study the matter of seed infecting diseases produced by seed infesting fungi. These seed infesting fungi are of two types, viz, first, those whose spores adhere to the seed grain as in the case of the smuts of grains generally, and second, and more exactly, those fungi which develop upon or within the seed largely by their threads or mycelium, and may, or may not, prevent the germination of the infested seed grain. Our knowledge of these strictly seed infesting fungi is quite recent; we may point to the work of Prof. Bolley and his assistants at the North Dakota Experiment Station, especially upon the matter of flax diseases; to the work of Dr. Halsted in New Jersey and to Bulletin 173 of this Station by Van Hook. With the tendency to continuous growing of flax, in the west there was developed an

that new area specific seed and soil troubles which have been proved to be perpetuated in the infected seed. An anthracnose of flax and a *Fusarium* attacking flax seed are examples.

No less conspicuous is the case of the blight fungus of peas, *Ascochyti pisi*, which is also an anthracnose, and the allied anthracnose of beans, *Colletotrichum lagenarium*. Investigations made at this Station by Van Hook show the source of the trouble with peas to be the infected seed employed and show also that seed treatment will not destroy these internal fungi without destroying the vitality of the seed. It was further shown that the source of relief lies in growing healthy seed through the use of fungicides upon the pea vines from which seed is gathered; likewise that infection may remain in the soil, (See Bulletin 173).

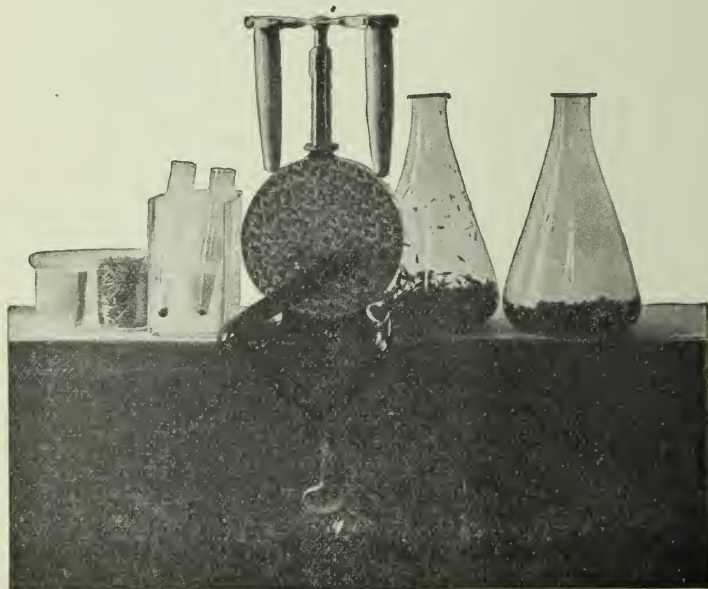


Fig. 14. Showing physician's centrifuge and other apparatus used in making examinations of grain washings for smut spores and spores of other diseases adhering to the exterior of seed. The flasks at the right show samples of washed grain. Those at the left show amounts of grain and water used. The glass tubes in container are used in the metal holders of the centrifuge. The precipitates in bottoms of tubes were obtained from washing of oats and wheat samples in flasks. (From Bul. 203).

More recent work at this Station has shown the presence of seed infesting and seed infecting diseases in wheat. (See Bulletin 203). The illustration, Fig. 15, exhibits the germinating seeds of wheat with the outgrowth of the parasitic fungus (*Fusarium*) which we find associated with wheat scab. This is upon seed grains (kernels) that are not destroyed by the fungus; many of the kernels of scabby

heads will not germinate. It was also found in continuous wheat land as much as 6 percent of the young wheat plants were destroyed in the fall by this same parasite which appears to survive in the soil under continuous wheat growing as well as to be propagated in the seed grain.



Fig. 15. This shows results from germinating ten wheat kernels in Petri dish containing agar. Both the agar and the kernels were sterilized. After five days it was found that five kernels had produced healthy plantlets, and four kernels had germinated but were attacked by the scab fungus, *Fusarium*, and two by another fungus. One kernel in the center did not grow and gave only growth of the scab fungus, *Fusarium*. (From Bul. 203).

HOW TO EXAMINE SEEDS FOR INFECTION

Recently good success has been obtained in the laboratory of this Department in determining the presence of certain seed infesting fungi in seed wheat, oats, rye, etc. In regard to the matter of adhering spores this is accomplished by making washings of the seed in distilled water and separating the spores from the washings by means of a physician's centrifuge. (Fig. 14). The spores and similar particles washed from the seeds are thus collected in the bottom of the tubes of the centrifuge and may be identified by microscopic examination. (Fig. 16).

Examples may be multiplied to illustrate the range of seed infection both by adhering spores and by internal development of the mycelium of the invading fungus. Many of these are treated under the particular diseases of the crops. The bean, pea, barley, broom-

corn, flax, millet, potato, sorghum, rye, sweet-potato, and wheat will all furnish examples. Not only have we to test the actual survival of the parasites thus found but we must discover the behavior of the disease with respect to the germination and seedling plants which grow from such infected seeds or tubers. Examination for infection of seed bulbs and tubers may be made either with or without the growth of



a

Fig. 16. Microscopic photographs from centrifuge precipitates of wheat washings. *a*, from wheat washings, narrow, slightly curved anthracnose spores, small spherical, loose smut spores, large spore of stinking smut and portions of the setae of anthracnose. *b*, from wheat washings, small, loose smut spores, large stinking smut spores and curved scab spores. All magnified about 180 times.



b

plants from them. With potato scab and rosette, the external scab effects or the sclerotia of *Rhizoctonia* are not difficult to see. With the latter the moistened tubers show

marked color contrasts and make the work easier. These diseases are reached by seed treatment.

Where the infection is internal by the threads or mycelium of the fungus, the seeds may be germinated in Petri dishes where the kernels are surrounded by a moisture retaining, sterile medium

such as agar or gelatin. This method has been worked out in Bulletin 203 and may often be applicable. The illustrations above will show the results in these cases as before referred to. With internal tuber infesting diseases as in the bacterial wilt disease of the potato, the *Fusarium* wilt or dry-rot fungus of the potato and the soil-rot of the sweet potato, we must go further than mere external examination. For the two named wilt diseases of potato, infection usually shows earliest at the stem end. Thin slices across this stem end of the tubers will show whether or not there is discoloration in the vessels. In the absence of infection there will be no discoloration with bacterial infection by *Bacillus solanacearum*, black areas or rings will be seen in these tissues while tubers infected with *Fusarium oxysporum* will show local areas of browned or blackened tissues. This infection applies usually to harvest time. As the infection advances, one-half the length of the tuber or even more may become infected. In all cases sections from sterilized tubers may be used as a source of cultures in Petri dishes. The same applies to soil rot of sweet potato. These diseases are not reached by seed treatment.

THE LIMITS IN SEED TREATMENT

It will be apparent that serious limits hold in regard to seed treatments. Where the spores are external and simply adhering to the seed grain, treatment will destroy these spores if rightly adapted to the seed in question and the germination need not be much, if any impaired. On the other hand where the seed infection is internal rather than external, grave doubts arise as to the possibility of successful seed treatment.



Fig. 17. Pea stem showing lesion from blight fungus, *Ascochyta pisi*, near surface of ground. This fungus came from the seed pea. (Natural size). From Bul. 173.

It has not been found possible in the cases of seed peas when infected with the blight fungus, or of seed wheat, rye, etc., infected with the scab and other fungi to apply any seed treatment which would destroy the infecting fungus without destroying the vitality of the seed grain. In general we may say that where the seed infection or fungus spores, etc., are external to the visible or germinable grain, seed disinfection through treatment is possible, but for the internal fungi it is rarely possible. The loose smut of wheat may be amenable to special seed treatment with only partial loss of vitality in the seed wheat.

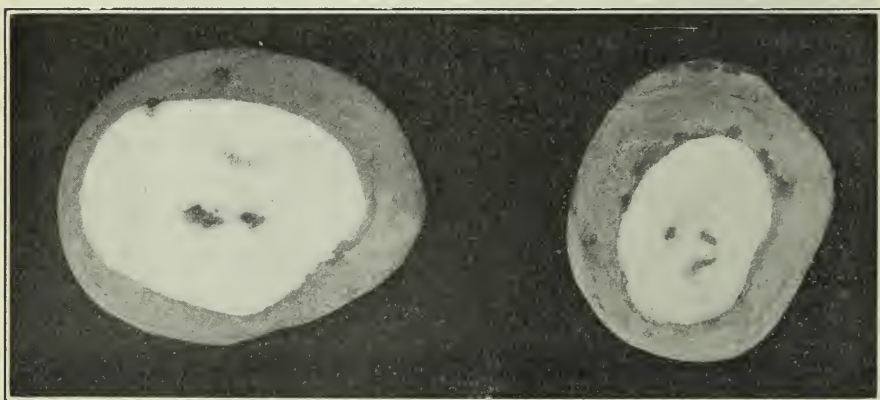


Fig. 18. Potato tubers attacked by Dry Rot *Fusarium*, showing sections near the stem-end of infected potato tubers. This infection may be easily discovered by cross sections made with a sharp knife, and sections from sterilized tubers gives cultures in Petri dishes. At times the discolorations extend to the middle of the tuber. (From a photograph by T. F. Manns).

METHODS OF SEED TREATMENT

The methods of seed treatment heretofore employed are set forth in the spray calendar and consist in an immersion of the seed in hot water of definite temperatures or in solutions of formaldehyde of different strengths. The formaldehyde solutions may also be employed to sprinkle piles of seed grain and in this manner less handling of the grain is required. More recently it has been proposed to disinfect seed potatoes, onions, forage, etc., through fumigation with formaldehyde gas liberated by boiling the solution, or better by mixing formaldehyde or formalin solutions with pulverized potassium permanganate by which the gas is liberated.

With seeds, tubers, roots, bulbs, etc., the limitations of the treatment are not so narrow and these may be immersed for longer or shorter periods in solutions of corrosive sublimate, formaldehyde, etc., or they may be exposed to fumigation with gaseous formaldehyde as has just been stated. (See Seed and Soil Treatment, pages 344 and 345 following.)

SOIL INFESTING PARASITES IN FIELD AND FORCING HOUSE

The cultivated soil is a medium in which many species of bacteria and fungi survive from year to year. The public is familiar with the doctrine of bacterial infection or inoculation of the soil in its relation to the nodules or tubercles of clover, alfalfa, soy beans, cowpeas and other cultivated plants of the Family of *Leguminosae*. One form of bacterium is not sufficient for both clover and alfalfa. This flora of the soil both in relation to bacteria and fungi of considerable range of species, is enriched by the applications of manure and by the practices of culture; by this is meant that the growing of a given crop a second time or a third time consecutively in the soil increases the probability that the plant roots remaining in the soil are carried over from one crop to the next together with root parasites which cause disease in the plants of this crop. Manifestly, likewise, if in preparation for a given crop to be grown for the first time upon the land, rather liberal applications are made of fresh stable manure containing spores or mycelium, more especially the resting forms of mycelium called sclerotia, the soil will become infected by this manurial application. While this source of infection is rather rare in field culture we have specific examples as in the scab disease of potatoes transmitted in this way; the scab of sugar beets may be carried in like manner. But in forcinghouse culture where heavy applications of manure are made, the chances are greatly increased that soil infection will be produced from the manure.



Fig. 19. Bases of potato stems (Carman No. 3) collected June 7, 1902, Cheshire Ohio, showing injuries by *Rhizoctonia*. The shaded areas are darker lesions occupied by an abundance of *Rhizoctonia* hyphae; the tops showed conspicuous Rosette effects. Reduced from Bulletin No. 139.

It is of value to remember that seed infesting or seed infecting organisms are also very largely capable of survival in the soil nidus of cultivated soils, thus our troubles multiply adequately if our care be inadequate to avoid them.

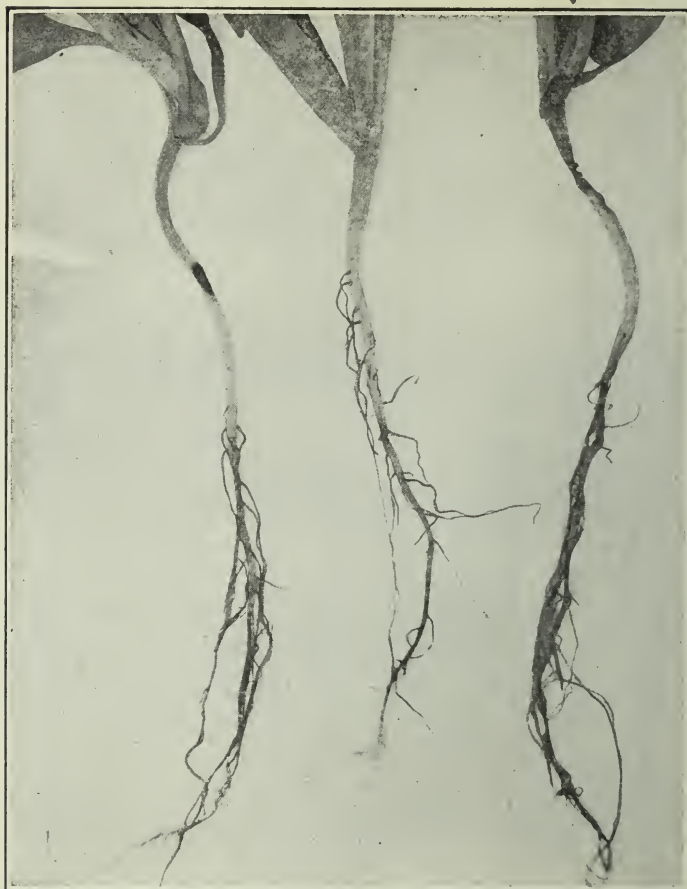


Fig. 20. This shows root portions of seedling lettuce plants with dark spots, lesions caused by attacks of the rosette fungus, *Rhizoctonia*. With the younger plants these attacks cause large mortality and in very small seedlings the stem of plantlet may early collapse after the manner shown in rotting specimens. (From Circular No. 57).

THE AVOIDANCE AND PREVENTION OF SOIL INFESTING DISEASES

We, perhaps, may assert that the law of nature is that of a diversified plant covering; at any rate the law of successful culture will permit of statement in terms of crop rotation. And it is true that as culture ages the number and seriousness of plant diseases increase almost in geometric ratio. It is further conspicuously true with respect to those areas devoted largely to continuous culture in a single crop or in a group of closely related crops such as the growing of wheat in Western United States and Canada, also in the growing of flax and other crops. Potato growing in San Joaquin county, California, illustrates this danger. Muck lands devoted to vegetable culture, tempt the grower to continue his crops of celery, onions, etc. Here we have as a true result the accumulation of diseases which attack these plants; thus for field culture we are constantly facing these problems of soil infesting diseases and the handling of the diseases is not an easy problem since change to rotation may mean

a serious decrease in the return from the crop on the special type of soil. While for general field culture avoidance of conditions may be successful, this is by no means a simple matter. Rotation is often absolutely necessary, but this same rotation will not rid the soil of the onion smut fungus, nor of some other parasites such as in the case of the club-root fungus of cabbage and related plants. In these cases some soil treatment must be applied to field areas. In the case of the onion smut it is sufficient to apply a formalin drip which will fall with the seed and disinfect the soil layer in proximity to the seed. This is effective because the smut fungus can penetrate the germinating onion plant only in the earlier stages of growth. On the other hand with cabbage club-root, where plants are transplanted from the beds in which they are grown, some general method of soil treatment which involves the soil mass is more effective. In this case it is the application of stone lime or caustic lime in liberal quantities. These examples are only illustrative of general conditions to be met with. In the case of potato scab, it is found necessary both to disinfect the seed where scab is present, even to a limited extent, and to plant upon new soil not infested with the scab organism. Potato rosette is certainly an acid loving parasite.



Fig. 21. Lower portion of two celery plants showing effects of root rot, *Rhizoctonia*. It will be observed that nearly all the roots of the plants have rotted off in consequence of the attack. (From Circular No. 72).

Under the diseases described for each plant, methods of avoidance and treatment are indicated and the diligent student will find other instances of similar character mentioned therein.

SOIL TREATMENT IN THE FORCING HOUSE

About our great centers of population have grown up conspicuous developments of the forcing house industry; large areas are covered with glass and these hothouses are maintained at the necessary temperatures for the production of the special green crops found profitable. At the same time the soil of the hothouse beds is very liberally manured and enriched further by applications of commercial fertilizers. Not only do these applications of manure tend to enrich the flora of the soil and to introduce particular root parasites, but the decay of the organic matter of the manure also tends to produce humus acids in considerable quantities. Along with these are brought parasitic eelworms which are peculiarly fatal to curcurbitaceous plants, to violets and to some other hothouse crops. Next to the eelworms the most conspicuous organism in our area is the sterile fungus *Rhizoctonia*, whose resting forms or sclerotia may be readily introduced in manure. To meet this indoor soil infection, special methods of soil sterilization had to be developed, since soil rotation is practically impossible in the forcing house.

These methods of treatment are in brief, steaming of the soil to render it practically sterile, so far as these parasites are concerned, and a method of formalin drenching. This method of steaming is ideal, or almost so, in its results upon sandy or loamy soils, but often entails unfavorable changes in heavy silty or clay soils. Essentially, it consists in burying a series of perforated pipes in the soil at intervals, covering the surface of the beds and passing live steam in sufficient volume into the pipes. These pipes are prepared in sets with cross heads and boiler connections and are perforated at desired distances. The surface of the bed is covered with canvas and the steam passed into the system for such period as is required to heat the soil to a temperature from 180° to 212° Fahr., to be maintained for one hour or more. This applies to high pressure boilers; for low pressure or hot water heating systems where the steam is applied in subdrains, four to five hours steaming will be required with a pressure of six to seven pounds. This treatment is effective for destruction of the eelworms or nematodes of cucumbers, violets and lettuce, the rot or drop fungus of lettuce, the rosette fungus, and in general of all soil infesting parasites.

Another method, the formaldehyde or formalin drench, has proved successful for the control of *Rhizoctonia* in greenhouse soils. This consists in a solution of 40 percent formaldehyde in water, say at the rate of two to four pounds in 50 gallons of water. This is applied at the rate of one gallon per square foot of area and will involve a very severe wetting down of the bed and prevent immediate resetting of the soil owing to the persistence of the formaldehyde. One secondary effect of formaldehyde drench and lime in sandy soils in the forcing house was an increased yield of lettuce amounting from 60 to 90 percent over the ordinary crop. This was explained on the assumption that the parasitic fungus was destroyed and certain other inhibiting organisms at the same time.

THE BEST FORCING HOUSE PRACTICE

The best forcing house practice will contemplate a recurrent disinfection or sterilization of the soil during the idle period; it should be preceded by whatever applications of limestone and manure that are to be made to the soil, then after thorough working and application of water to correct unevenness of moisture the soil may be sterilized by steam, or the formaldehyde drench be applied with assurance of results: obviously also this treatment must extend most vigorously to the plant beds and bring healthy seedlings to soil in which the soil parasites have been destroyed.

The following tables of seed and soil treatments taken from the spray calendar will be of more use than extended description or discussion:

SEED AND SOIL TREATMENTS

SEED OR PLANT	FOR WHAT TREATED	TREATMENT	METHOD OF TREATMENT
Barley	Smuts	Formaldehyde or molified hot water	Sprinkling with stronger formaldehyde as for oats is successful. Soak seed enclosed in sacks four hours in cold water, let stand wet four hours more and dip five minutes in hot water at 136 degrees Fahr., or three degrees lower than for other hot water treatments.
Bean	Anthraxnose	See spray calendar	
	Woevil	Bisulfid of carbon	Submit to fumes for twenty-four hours in air-tight vessel or chamber.
Begonia	Nematodes	Sterilize soil with steam	Disinfect soil to be used by heating with steam as described under cucumbers.
Cabbage and Cauliflower	Club-root	Quicklime on soil	Apply stone lime (quicklime) preferably ground lime, before planting, at rate of 80 bushels per acre and work into the soil with suitable tools.
	Maggot	Bisulfid of carbon or tobacco dust	Make hole in soil near root, pour in about a teaspoonful of bisulfid of carbon and fill holes with soil. Cover soil around stalks freely with tobacco dust once per week.
	Nematodes in hothouse	Sterilize soil with steam	See next.
Cucumber	Nematodes in hothouse	Sterilize soil with steam	Sterilize soil with steam by perforated pipes, high pressure, 1 to 2 hours, or low pressure in subdrains 4 to 5 hours.
	Root-rot	Drench soil with formaldehyde or sterilize as above	Drench soil with formaldehyde 3 to 4 lbs. to 50 gallons of water preceding lettuce crop.
Lettuce	Rosette	Sterilize soil with steam or drench with formaldehyde	Steam as above or drench with formaldehyde 1½ to 2 lbs. where trouble follows with cucumbers use 3 to 4 lbs. to 50 gals. of water, 1 gal. solution to each sq. ft. of surface. Two weeks must elapse before setting plants.
	Rot	Steam soil	
Oats	Anthraxnose	Formaldehyde	Treat seed as stated in next to kill adhering spores. This is only a partial remedy.
	Loose smut	Sprinkle seed with formaldehyde or immerse seed in hot water. Soak seed in potas. sulfid...	{ Preferably sprinkle a pile of seed with shoveling to saturate with formaldehyde solution, one gallon to bushel, at three or four sprinklings; after three or four hours or over night in the pile, spread to dry. Immerse seed contained in open vessel for ten minutes in hot water at 132-3 degrees Fahr., for seven minutes at 136 degrees Fahr., or for five minutes at 140-2 degrees Fahr., spread at once to dry. Soak seed in ¾ percent solution potassium sulfid for 24 hours with stirring, then dry.
Onion	Insects in stored grain	(See wheat)	
	Smudge	Use formaldehyde as for onion smut	Sow seed with formaldehyde as for onion smut; rotate onions with other crops.
	Smut	Use formaldehyde or ground quicklime. Plant other crop. Use sets or transplanted seedlings.	Use formaldehyde solution 1 lb. to 30 gals. of water sprinkled on seed in contact with soil and cover at once, or better sow with drill and drip attachment, the solution falling with the seed. Or apply ground quicklime at the rate of seventy-five to one hundred and twenty-five bushels per acre just previous to seeding on freshly plowed land, and stir into soil. (See Bulletin 131).

SEED AND SOIL TREATMENTS Concluded

SEED OR PLANT	FOR WHAT TREATED	TREATMENT	METHOD OF TREATMENT
Onion	Storage-rots	Disinfect with formaldehyde gas	Fumigate to disinfect the dry onions, with formaldehyde gas in enclosed piles of slat crates for a period of 24 to 48 hours. (See description of method under fungicides).
Pea	Anthraxnose (Blight)	Spray the growing crop with Bordeaux	Keep down infection of seed through spraying of plants. See Spray Calendar.
Potato	Scab	Soak uncut seed in formaldehyde or corrosive sublimate	Soak seed for two hours in formaldehyde or one hour in corrosive sublimate; then dry and plant on scab-free soil; formaldehyde gas may be used.
	Rosette (Rhizoctonia)	Soak seed in formaldehyde as for scab	Soak seed in formaldehyde as for scab; on infected soil use formaldehyde after manner in onion smut. (See Bulletin 145).
Roses	Nematodes in hothouse	Sterilize soil with steam	Heat soil with steam as described above; thoroughly disintegrated soil from sod one year or more old is less dangerous. Lime water stimulates affected plants but is not a remedy.
Rye	Anthraxnose	Formaldehyde	Treat seed as for oats and wheat to kill spores. Remedy only partial.
Sweet Potato	Black-rot and Stem-rot	Formaldehyde	Soak or fumigate seed roots as for potato scab; discard old diseased hotbeds; drench slightly diseased beds with formaldehyde as for lettuce and tobacco. Then set plants on new soil.
Tobacco	Root-rot and Bed-rot	Drench beds with formaldehyde or sterilize with steam	Drench beds in fall or early spring with formaldehyde 2 lbs. or more to 50 gals. water, 1 gal. to each sq. ft. Do not seed until smell of formaldehyde has disappeared.
Tomato	Nematodes in hothouse	Sterilize soil with steam	As for roses and cucumbers above.
	Point-rot in hothouse	Mulch or sub-water	An insufficient water supply seems favorable to development of point-rot of green tomatoes.
Turnip	Club-root	Quicklime in soil	As for cabbage and cauliflower. A void succession of these crops.
Violet	Nematodes in hothouse	Heat soil with steam	The time for prevention is by soil treatment beforehand as for cucumbers above.
Wheat	Anthraxnose	Formaldehyde	Sprinkling as for stinking smut may prove partial remedy.
	Loose smut	Modified hot water	Soak seed four hours in cold water, let stand four hours more in wet sacks, immerse five minutes in water at 133 degrees Fahr. and dry.
	Stinking smut	Formaldehyde, hot water or copper sulfate	Sprinkle grain in piles with formaldehyde as for oat smut, 1 gal. or less per bushel and dry in same manner. Dip skimmed seed for ten minutes in hot water at 133 degrees Fahr. and dry on disinfected surface or immerse ten minutes in solution of blue vitriol (copper sulfate); dry with air-slaked lime by shoveling. Use two pounds of blue vitriol to ten gallons of water. Grain may be sprinkled in piles with copper sulfate or formaldehyde as for oats. (See Bulletin 97).
	Insects in stored grain	Bisulfid of carbon	Place one pound of bisulfid of carbon for each 2,000 pounds of grain in bins. Cover surface with blanket to hold the fumes which will spread through the mass, killing all insect life. Use in tight bins or buildings and do not use near fire of any description.

ROOT DISEASES AND ROOT-ROT FUNGI OF ORCHARDS

Diseases upon the roots of herbaceous plants are very commonly due to soil infesting parasites. As explained under that topic, the soil conditions may be favorable to certain parasitic organisms or without being especially suited to them soils become infested with fungi which tend to remain indefinitely and become a source of loss in crops and effort. See lettuce rosette, tobacco root-rot, potato dry-rot and root-rot of violet.

The root-rots of woody growths are commonly more or less truly wood invading fungi of the semi-parasitic type and become of interest to foresters as well as orchardists. A partial exception to this wood-invading character of these root-rot fungi is found in a recently discovered development of the tobacco and violet root-rot fungus, *Thielavia basicola* Zopf., upon catalpa seedlings in nursery. However, since even tree seedlings in their early stages have not developed their woody tissues to any great extent, they are susceptible to the same root parasites as are found on herbs. This will likely explain cases like that cited on catalpa and the trouble may pass as the seedlings become older. Yet it must be confessed that this still raises a question as to the effect of the general parasitism of even *Thielavia* upon the rootlets of trees like catalpa.

In forest woodlots, root-rots are likely to become of increasing effect. Wherever these tend to limit the reproduction of certain species in the woodlot, they will be injurious. In this respect they may prove an added reason for the rotation of conifers with deciduous growths. In coppice or cut-over lands such as prevail in the charcoal furnace districts of Ohio, the roots and stumps of the parent stem must be an eventual menace to the new growths which spring up about them. The exposure to the wood fungi which become timber or heart-rot sorts will be very great in all such cases. The gradual invasion of the new growths must often occur when these approach a size that gives a considerable heartwood cylinder. These are the great sources of trouble in coppice reproduction of timber trees.

Root-rots in orchard plantings are known more especially when these are made following oak and other species somewhat after the manner of coppice conditions. The rhizomorphic development of these root-rots is difficult to determine but is usually referred to *Agaricus melleus* (*Armillaria mellea*). See root-rots of apple, peach, etc.

An especial feature to be noted in root-rots of all sorts are the soil conditions as to excess moisture and aeration of the soil. In silty or clay soils of close texture and coagulable nature, with excess moisture, serious conditions arise. Any traces of root-rot fungus

under such conditions will involve increased risks. The necessity for drainage will usually be apparent and due consideration of the limits of certain orchard trees needs also to be given. Cherry trees and even peach and apple trees will not survive under moisture conditions wherein plum and pear trees may grow with profit.

Orchard replants in "clinker" locations wherein failures have been numerous, will raise these questions of root-rots and relative adaptability of different orchard trees. Rotation planting, as pear or plum after apple, plum after cherry, etc., may at times succeed and replace unsightly gaps in the orchard by flourishing trees of another sort. At present, drainage and aeration are our known methods of restricting root-rots under out-door conditions.

PARASITIC FOLIAGE DISEASES

Foliage diseases of every sort are caused by oxygen loving or aerobic species of parasites, and very often this development on the leaves consists of the imperfect forms of the fungus life history. These forms are none the less aggressive and injurious for this reason, but the exact manner of survival from year to year becomes important wherever not known. The application of this to preventive measures in the control of these diseases upon foliage and fruit is seen in the case of apple scab, the monilia rot of plums, peaches, cherries, etc., and in apple bitter-rot. These last two rot troubles survive in the "mummy" or dry rotted fruits and this explains the reason for the oft repeated injunction to destroy all "mummies" in addition to spraying operations. The bitter-rot of apples is propagated by means of summer branch cankers on the tree, as brought out in recent years. Other leaf forms survive on the fallen leaves or possibly in bud scales as with the leaf curl and "bladders" of the *Exoascae*. A large number must live over on the branches.

Parasites upon foliage soon become apparent from the spots on the leaves and dropping of fruit resulting. This dropping may come as a result of impaired vigor by reason of disease—when it is later, but is more often the direct result of parasitic attack by the disease upon the young fruits. Herein as elsewhere the philosophy of fungicides comes to our relief. A good foliage fungicide is a relatively insoluble compound which will not greatly injure the leaves with which it is in contact. The remedies for foliage troubles are applied in *anticipation of attack* and for the purpose of checking the fungus when it may appear. The relative efficiencies of various fungicides in early summer will possibly depend upon the sticking qualities of the sprays.

Foliage diseases, moreover, are liable to recur each year and this is an added reason for anticipatory treatments to ward them off. *Foliage diseases may not be neglected with impunity since the leaf is the plant's vital working organ and the plant must suffer from its impairment.*

BITING AND SUCKING INSECTS AND LEAF DISEASES

The part played by insects which wound the leaf epidermis, in the spread of leaf diseases, is often very important. Such wounding



Fig. 22. Showing sections of blades of oats attacked by green lice (aphides). The right hand specimen shows type of injury resulting from the sucking of the aphis. In case these lice are carrying the organisms of oat blade blight, this sucking will lead to infection by the disease. (From a photograph by T. F. Manns).

of the leaf or green stem whether by insects such as flea beetles, foliage eating worms, or by sucking insects such as mites, leaf hoppers and plant lice, opens the way for the spores of parasitic fungi or of bacteria or mere molds, any one of which may be injurious to the leaf. The early blight disease of potatoes is a good example. In seasons when there are many of these little black flea-beetles to puncture the leaves, the thorough control of both these insects and the early blight, *Alternaria* fungus, is called for. Many fungi of doubtful penetrating powers are truly injurious when they follow insect punctures of the leaves. Fortunately both these are se-

secured by Bordeaux sprays. The reasons for such applications are of double character since they are to combat both the insect and the fungus to follow it.

With shade trees the leaf hoppers and mites may be so numerous that tip-burn and various leaf dying results from the injuries or punctures they inflict.

A more startling relation is that of the blade blight of oats, a recently investigated bacterial trouble. This bacterium is distributed and inoculated very obviously by the aphids or green flies (plant lice), and other sucking insects which prevailed during the seasons of 1907 and 1908 upon oats almost throughout Ohio. For fuller details see Blade Blight under Oats, and Bulletin 210.

WOUNDS AND WOUND INFECTION

With woody growths, especially in trees which attain considerable size, we have the various phenomena of disease infection through wounds; this infection later becoming evident by reason of decays set up in the woody tissues. Of course, in instances such as the bark disease of the chestnut, *Diaporthe parasitica* Murr., the disease may penetrate the living tissues. Not so, generally, in wounds of woody plants. Any large woody growth, as, in forest or shade trees and in larger fruit trees, shows the combination of an external or living sapwood layer and an internal dead or heartwood cylinder. The commoner forms of wound infections are attributable to those species of fungi which cause decay of this dead heartwood. Among these are the long list of saprophytic, agarics, polypores and stereums. Because of the fact that this heartwood cylinder is dead, these saprophytic species of fungi, once they gain entrance into it, flourish there and invade the wood to a very great extent, even by adaptation to parasitic habit extending their work into the living parts causing death. The removal of a large branch of a shade tree or a fruit tree, unless the wound thus

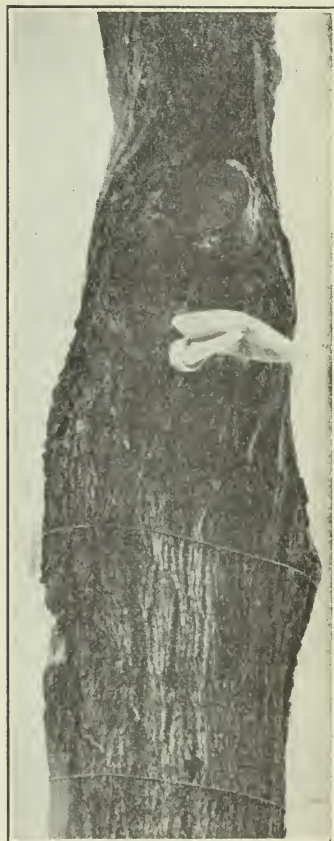


Fig. 23. Maple shade tree, Wooster, with large branch cut off. Below this cut the wound fungus, (*Volvaria bombycina*) has developed and fruited; the cap is nine inches across. This shade tree was further wounded by wrappings of wire to stiffen a telephone pole. (From a photograph by J. M. Goheen).

formed is properly protected by dressing, opens the way for spores of these fungi which cause timber decay to obtain a start and thus eventually to invade the heartwood of the interior. For dressing cut off branches, asphaltum is admirable; in its lack gas tar is good, and either is better than ordinary paints.



Fig. 24. A wound parasite (*Pleurotus ulmarius*) on the trunk of a maple tree. (After Freeman, Minnesota Plant Diseases).

There is always to be borne in mind that the protection of the woody cylinder of trees depends on its being covered by the living layer of sap wood. Every branch of considerable size connects directly with the extensive heart cylinder; we thus see that the wound fungi which attack the heart wood are the timber decays and their presence emphasizes the need for care in providing protection for all wounds, especially those caused by pruning.

Any decay becoming established in the dead heartwood may extend for long distances through this dead wood and in the end so destroy it as to be in a position to invade the external or sapwood layer.

In addition to the exposure of the internal woody cylinder to these decays, we have sap-rots due to various species of fungi which belong on the border line between the parasitic and saprophytic sorts: Among them are species of *Fomes*, *Polyporus*, *Lenzites*, etc. Any wound of the sapwood even though it does not reach to the dark heartwood, exposes to the danger of this infection, and with infection, to all the consequences of sapwood decay and premature death of the tree. These decays and those of heartwood are in line with those of the rots of structural timbers, but we are at this time interested only in their effects on the parts of the living plants.

TIMBER ROTS AND TIMBER PRESERVATION

The decay of dead logs, wooden frameworks, or other structural timbers is caused by the attacks of saprophytic fungi belonging to the gill and pore fungi mentioned under wounds; these are of the great class of basidium bearing fungi, to which the fleshy forms, everywhere more or less abundant, belong. The most of them are included in the "mushrooms," which there is a strong impulse now to study and illustrate by photographs. These timbers are dead and are subjected to invasion by timber infecting species wherever the conditions as to air and moisture are such as to favor their development. Dry timbers are not subject to such attack because lacking the requisite moisture for the organism. Floors and other timbers of houses adjacent to the earth or to unheated cellars are often attacked by rot-causing species. The timbers of trestles, railway ties and the bases of fence, telephone and telegraph posts, where inserted into the earth or in contact with it, are kept sufficiently moist to invite attacks of this sort.

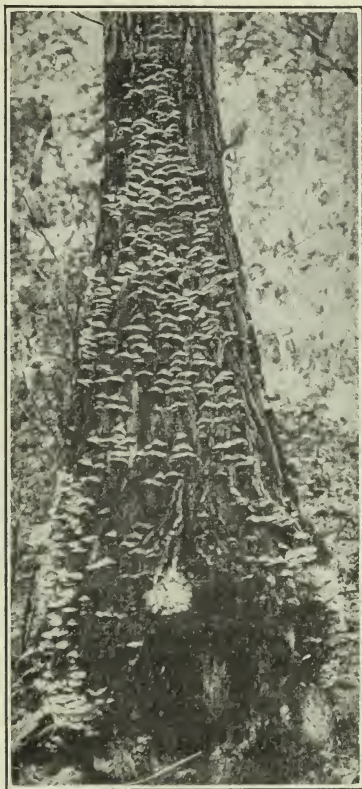


Fig. 25. Another wound parasite (a species of *Stereum*). The fungus obtained entrance in the wound at the base of the tree (an oak), and as shown by the fungus fruiting bodies, is gradually progressing upward. This tree died about a year after the photograph was taken. (After Freeman).

Wood that has been invaded by such fungi is reduced to the state called punk: that is, the wood fibers and arrangement in vessels to which the timber owes its strength, are broken down by the invasion of the fungus which flourishes at the expense of this woody tissue. There is no help for timber after it has once been attacked by rot fungi. Whatever preventive measures are taken must precede

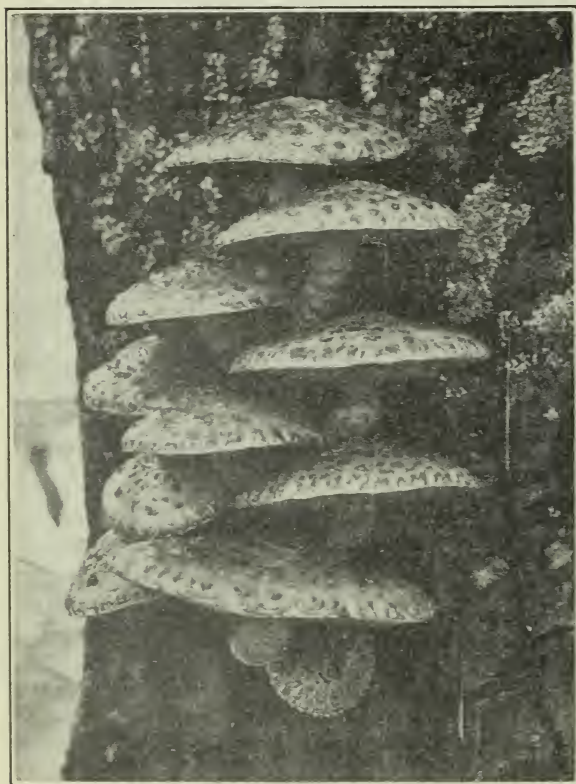


Fig. 26. Fruiting bodies of the fatty Pholiota (*Pholiota adiposa*), in a wound of an oak tree trunk. (After Freeman).

the attack. The most effective means of timber preservation is to cause it to be injected or permeated with creosote or other antiseptics. This is done by placing the timbers in vats containing the solution and extracting the air from the timbers so far as possible. The permanence of the effects of such timber treatment depends upon the resistance offered by the material used to gradual solution by water. In the case of creosote the results are quite satisfactory; with chlorid of zinc, subsequent solution takes place too readily, while

with crude petroleum there is a tendency toward the evaporation of this substance when injected. The increasing cost of timber will stimulate timber treatments by making treatment profitable. One drawback at present is the necessity to import creosote for use in such work; possibly refinery by-products from petroleum of a character analogous to asphaltum may find application in timber treatment.

ATMOSPHERIC CONDITIONS AS AFFECTING PLANT DISEASES

The relation between weather and the prevalence of certain plant diseases has been often recorded. The diseases which prevail are none the less parasitic, the difference exists solely in the temperature and moisture conditions of the atmosphere. Here we must distinguish clearly between the *cause* of the diseases and the *conditions* which favor the given diseases.

Certain parasitic fungi develop more rapidly under cooler conditions than the normal or average while others are favored by higher temperatures; all fungi are favored by large amounts of moisture when these stop short of water immersion and shutting out the needed air. In temperature we have an optimum which usually lies within certain maximum and minimum limits for any given species, but this temperature optimum varies with the organism; it is a matter which admits of exact determination for any organism. As to moisture, an abundant supply of water is the optimum for most fungi with which we deal in plant disease investigations.

In these atmospheric conditions of temperature and moisture the seasons of the year, in our climate, vary one with another. The seasons of heavy rainfall are commonly those of low temperatures by reason of the check on temperatures exerted by evaporation. Further, our weather service records show a tendency for our seasons to come in groups of cooler alternating with groups of warmer seasons; that is, we may have several years as with 1904 to 1907 (excepting parts of 1906) in which the mean monthly temperatures of those months which affect crops were decidedly below the normal or average. Evidently this normal lying as it does between the extremes, is surpassed by the warmer seasons which are said to be above normal. We have likewise, other alternating groups of years in which the season's temperatures are decidedly above the normal.

The effects of these cool seasons upon diseases are most clearly shown in outbreaks of leaf-curl of the peach and plum bladders in early season, and of potato late blight and rot, *Phytophthora infestans*, upon the potato crop. It is understood that plenty of moisture is the usual accompaniment of a cool season; from the combined effect of this supply of moisture and cool weather we have outbreaks of the potato disease even in northern Ohio where it does not appear certainly to survive from year to year. Such groups of cool seasons culminate as a rule in particularly injurious outbreaks of the potato *Phytophthora* with us; in more northerly situations, the disease is present nearly every season, but the outbreaks culminate with favorable weather conditions of excessive rains and lowered temperatures.

Stress has been laid upon the downy mildew of potato and cucumber respectively. It must not be inferred that other diseases do not offer like contrasts between dry, hot seasons and those of heavy precipitation and low temperatures accompanied by relatively high atmospheric humidity. Mention has already been made of the greater prevalence of the shot-hole disease of the plum and leaf-spot of cherry, *Cylindrosporium padi*, in rainy seasons over drier ones. The same facts will apply with respect to practically all external parasites of plants as in the scab fungus on the apple, the rot of plum, cherry and peach, and to the countless number of foliage diseases with which we deal from year to year.

Contrasting with the potato *Phytophthora* is the allied disease of curcubits, the downy mildew, *Plasmopara cubensis*, which appears to flourish during our hot seasons and to disappear during the cool ones where grouped as above described. The writer has suggested that this *Plasmopara* does not survive in our climate but is carried northward each year by its conidia alone; the extent of spread will thus be limited by the length of period favorable to it. This period must be one of relatively high temperatures since this parasite is more widely distributed near the tropics. All these instances only make more clear the intricacies of the mutual adaptations of parasite and host which have resulted from the long periods in which these dwell together.

MEAN SUMMER TEMPERATURES AND RAINFALL IN OHIO, 1883-1909

Year	Mean temperatures degrees Fahr.					Mean Rainfall, inches				
	May	June	July	August	Three months Mean	May	June	July	August	3 Mos. Total inches
1883.....	58.0	69.0	72.1	68.2	69.8	5.72	4.25	4.16	1.88	10.29
1884.....	60.4	71.1	71.5	70.8	71.1	3.87	2.96	3.83	1.45	8.24
1885.....	59.5	67.1	75.2	68.9	70.4	3.97	4.34	3.20	6.33	13.87
1886.....	62.2	67.5	72.0	70.9	70.1	4.23	3.53	2.88	3.62	10.03
1887.....	66.0	71.0	77.9	77.9	75.6	2.87	3.85	2.16	2.39	8.40
1888.....	58.8	70.4	72.1	70.4	71.0	3.77	3.41	4.40	5.16	12.97
1889.....	60.2	66.7	72.5	69.1	69.4	3.71	4.13	4.25	1.50	9.88
1890.....	59.2	73.3	73.0	68.8	71.7	5.52	4.50	1.99	4.70	11.19
1891.....	58.0	71.0	69.0	70.0	70.0	2.20	4.82	3.82	3.07	11.71
1892.....	59.0	73.0	73.0	71.0	72.3	6.32	5.61	3.80	2.99	12.40
1893.....	58.3	70.6	74.5	70.7	71.9	4.97	3.34	2.49	2.17	8.00
1894.....	60.0	71.3	74.3	71.2	72.3	4.00	2.65	1.56	1.67	5.88
1895.....	61.1	72.0	71.6	73.5	72.4	1.80	2.47	2.00	2.96	7.43
1896.....	67.9	69.5	73.2	71.8	71.5	2.67	4.81	8.11	3.38	16.30
1897.....	56.3	68.1	75.5	69.4	71.0	3.93	2.85	4.65	2.72	10.22
1898.....	61.0	71.9	76.0	73.5	73.5	4.10	2.86	3.98	4.50	11.34
1899.....	63.3	71.5	74.1	73.7	73.1	4.32	2.96	4.18	1.82	8.96
1900.....	62.9	69.8	74.1	76.3	73.4	2.40	2.99	4.62	3.68	11.29
1901.....	59.0	70.9	78.1	73.1	74.0	3.69	4.38	2.73	3.32	10.43
1902.....	62.6	66.9	74.0	67.4	69.0	3.09	7.48	4.69	1.67	13.84
1903.....	63.9	64.4	72.9	70.7	69.3	2.82	3.97	3.67	3.20	10.84
1904.....	60.7	68.4	71.4	68.8	69.5	3.79	2.88	4.13	2.74	9.75
1905.....	60.7	69.2	73.0	71.7	71.3	5.63	4.72	3.93	4.46	13.11
1906.....	61.3	69.8	72.1	74.6	72.2	2.17	3.41	5.14	4.77	13.32
1907.....	54.5	65.6	72.6	69.5	69.2	3.47	4.57	5.36	2.48	12.41
1908.....	62.8	69.2	73.9	71.2	71.4	4.72	2.52	4.08	2.59	9.19
1909.....	58.7	70.1	*69.6	*70.3	70.0	4.72	5.86	*4.05	*5.21	5.04
Ohio, '83-'09.....	60.6	69.6	73.44	71.3	71.4	3.88	3.93	4.08	3.12	10.82

* Records Wooster only, not included in other than 1909 averages.

The blade blight of oats, a bacterial disease, has been found to be much influenced if not largely controlled by atmospheric conditions and perhaps more especially those of the earlier summer. These factors have been recently presented by a bulletin of this Department (See Bulletin 210). This publication contains a fuller table with respect to early summer atmospheric conditions. The development of the *Fusarium* blight and dry-rot fungus as a widespread and serious disease of potato plants causing premature dying and reduced yields is of interest here. The outbreaks in Europe seem to be associated with atmospheric conditions in spring and early summer. We need fuller studies on these inter-relations.

Insistence is here again made upon the observed relations between atmospheric conditions and parasitic diseases of plants that the grower may be stimulated to greater effort at close observation when the need exists and the student may be aided in his interpretation of the vast array of apparently inconsistent and complex facts by which he is to be instructed.

REMEDIES FOR PLANT DISEASES--FUNGICIDES

In no other line of applied science has America made more rapid progress than in the matter of plant disease remedies. While the general doctrine of parasitism and the transmission of parasitic diseases are thoroughly investigated and widely published in Europe, the application of remedies and the interest in disease prevention fall much behind the practices in America. Indeed, the writer's attention was in 1908-9 forcibly called to this matter by the statement of a prominent American Pathologist as to the relatively great advancement in America over the old world in this regard. Probably this greater progress is due to the greater readiness with which Americans engaged in crop production, accept the teachings of scientists and make practical applications of the results obtained.

Among remedies for plant diseases we must include all treatments which tend to restrict or prevent the recurrence of diseases, that is, all treatments which remedy infections or limit the spread of parasitic attack.

SEED AND SOIL TREATMENT

Seed and soil treatments naturally belong here; while somewhat full discussion has been given on pages 342-345, it is necessary to recall the measures employed in seed treatments as well as in soil disinfections. In the seed treatments high temperatures, as in the hot water, or the application of a germicide as in solutions of formaldehyde are applied to the seed grain to destroy adhering

spores. In the treatment of tubers and roots as the potato, etc., longer soakings with solution of formaldehyde or corrosive sublimate are required to kill not only external spores but resting forms of fungi such as sclerotia, etc.

With soil treatments we have the problem of killing out soil infesting organisms such as nematodes or eelworms and *Rhizoctonia*, *Botrytis*, lettuce drop, etc., among the fungi. All these results are obtained by thoroughly steaming the soil. In a measure the same results are also obtained from a formaldehyde drench as elsewhere described.

Fumigation for the destruction of seed infesting fungi or cutting infesting insects is of the same character and must be named here. The fumigation of nursery cuttings with hydro-cyanic gas is effective as is also the fumigation of stored grain with carbon bisulfid. We must also consider that wound coverings are methods of prevention in plant disease, since these coverings of asphaltum creosote, gas tar, paraffine and even of paint serve the purpose of excluding wound fungi which might otherwise cause serious decays. All these treatments that have just been enumerated apply to the treatment of the soil or of seeds and plants in resting condition. The great problem of keeping down infection during the growing period yet remains for the application of spray mixtures.

SPRAYING WITH FUNGICIDES--INSOLUBLE COPPER COMPOUNDS

The progress made in the control of plant diseases through sprays since Millardet's discovery of Bordeaux mixture (bouillon bordelaise) near Bordeaux, France, in 1883 shows how great was then and is still, the need for effective fungicides. The materials from which Bordeaux mixture is made consist of copper sulfate (blue vitriol) calcium oxid and hydroxid (caustic lime) and water. In the making of the mixture the copper sulfate is dissolved in water and should be diluted with a considerable amount of water; the lime is slaked or converted into lime putty from which a milk of lime is prepared. These two mixtures with the copper sulfate in aqueous solution and calcium hydroxid in suspension, mixed together make a chemical reaction by which the calcium in the lime displaces in part the copper in the copper sulfate, forming on one hand calcium sulfate or gypsum, and on the other the various combinations of lime with the metallic copper thus liberated. The actual reactions have been variously interpreted. More recent investigations show that several basic sulfates of copper and lime are produced. Whether any hydroxid of copper is produced has been questioned by Pickering, an English investigator. The light blue color is due to suspended

particles of these compounds which are evidently the effective agents in fungicidal action. These insoluble light blue copper compounds which, in this divided condition, are held in suspension in the liquid give it the characteristic color. The essential needs in making Bordeaux mixture are the presence of enough or even an excess of the base, calcium (lime), so that none of the copper will remain in soluble form as sulfate. This on the other hand involves the more or less complete change of the soluble copper into relatively insoluble, blue-colored copper compounds of another sort.

The philosophy of spray action is based first of all upon the absence of injurious effects from the lime products and from the copper compounds produced, when sprayed upon green foliage. In the second place, upon the effectiveness of these insoluble copper compounds through solution in the presence of moisture and carbon dioxid in the atmosphere, to destroy or prevent the growth and development of parasitic fungi. The time during which these insoluble copper compounds will be effective must depend upon the rate of growth in the plant parts and the adhesiveness of the application. The essential feature to be remembered is this; the insoluble or slowly soluble copper compounds become available by solution as needed. Where excess of fungicide is employed this has a certain danger upon apple or other foliage during showery weather and in all cases the strength is adapted to the host crop. Coincident with the spraying period there is frequent complaint of injury to apple foliage. Here we have solution effected more rapidly than is safe for the host; normally this risk is slight, but may be overcome by necessary modifications. Another matter is the amount, the number of gallons of the given fungicide to use; with more complete spraying appliances and high pressure of application, larger amounts and more complete covering of the parts are the rule. Recent results show that when the amount of copper in the mixture is near to the danger line these heavier applications increase the risk.

In the early translations from the French the strength of Bordeaux mixture was placed higher than is now the practice. For Ohio the following formula has been the rule for many years:

STANDARD BORDEAUX MIXTURE

Copper sulfate (blue vitriol).....	4 pounds.
Caustic lime (unslaked).....	4 pounds.
Water to make.....	50 gallons.

This is a 4-4-50 formula—a 2-2-50 formula is also used at times.

In making Bordeaux mixture, the copper sulfate may be dissolved in hot water (about 2 gallons) or better by suspending the sulfate contained in cheese-cloth sack, in a large vessel of cold water.

By using large quantities of both blue vitriol and water, say 50 pounds of copper sulfate and 50 gallons of water, a stock solution may be prepared, so that each gallon will contain one pound of the blue vitriol. In each case the solution of copper sulfate should be diluted say to one-half of tank capacity before admixture with the milk of lime.

The quicklime is slaked and then stirred to make milk of lime, adding water as needed to do this. The necessary amount of this milk of lime should be diluted to about 40 or 50 percent of the tank capacity and then run into a mixing tank with equal flow of corresponding volume of copper sulfate solution *before same is run into spray tank or barrel*.

All Bordeaux mixture formulae are useful as a vehicle in which arsenical sprays are added to serve as insecticides.

THE USE OF STICKERS IN SPRAY MIXTURES

Some experiments made in different parts of the country have shown beneficial results from the use of other materials added, such as sugar solution, soap, resin soap, etc., to increase the adhesiveness of the spray. In some spraying experiments by the Entomological Department of this Station, laundry soap was used effectively as a sticker to hold arsenical compounds in checking the berry worm or grape worm (See Circular No. 63).

The writer has proposed a modification of Bordeaux mixture which has been called "Bordeaux Mixture and Iron Sticker."

The following formula has been recommended:

BORDEAUX MIXTURE AND IRON STICKER

Copper sulfate (blue vitriol).....	2 pounds.
Iron sulfate (copperas).....	2-4 pounds.
Caustic lime.....	4-6 pounds.
Water to make.....	50 gallons.

In this spray the iron sulfate is added in order that it may be precipitated by the lime and serve as a more complete sticker than is provided by the standard Bordeaux mixture. It would appear possible by the weak solution as given for the copper compound and by this possible efficient sticker to make the reduced amount of the copper sulfate do the work as fungicide just as effectively and with less risk of foliage injury than with the standard Bordeaux mixture. The trials made up to this time upon apples in full foliage, upon grapes and upon potatoes indicate that the spray is efficient. *The iron sulfate is not considered a fungicide.*

SOLUBLE COPPER COMPOUNDS AS SPRAYS

Whenever it becomes necessary to continue spraying upon fruit as ripening approaches a more soluble copper compound than Bordeaux mixture must be employed or the spray will remain upon the fruit at marketing. The remaining spray, if excessive, injures the marketable character of the crop. Various sprays have been proposed for use at these critical times. The call for them has come in keeping down the black-rot on the grape and in the control of the several late season diseases of fruit, like the bitter-rot and black-rot of apple. The most satisfactory soluble copper sprays appear to be ammoniacal solution of copper carbonate or Soda Bordeaux mixture.

For the former the following formula is given:

AMMONIACAL SOLUTION OF COPPER CARBONATE

Copper carbonate.....	6 ounces.
Ammonia	about 3 pints.
(Enough to dissolve the copper carbonate and no more).	
Water to make.....	50 gallons.

This is an effective spray made according to formula for the late applications upon grape and upon apple as maturity approaches. It is to be understood that this formula is not intended to make "eauceleste" which is a different preparation. No more than enough ammonia is added to convert the copper carbonate from insoluble to soluble form in the presence of water. A soluble salt of ammonia and copper is really produced. The proper times at which to make applications of fungicide as sprays has been carefully worked out in practice and directions are included in the spray calendars. There is a good reason in nearly every case for making the applications at the time recommended, since these sprays are timed to check the development of the parasite; if put on too long in advance the spray may be displaced, if put on too late the damage will occur without a possible means of prevention. All sprays as stated before are made in anticipation or in advance of actual danger from parasitic diseases.

SULFUR COMPOUNDS AS FUNGICIDES

Various preparations of the sulfids of alkalis and alkaline earths have been proposed as fungicides. A larger use has been made of the lime-sulfur formulae which have come into use largely for checking scale insects. These mixtures are made by boiling together caustic lime and flowers of sulfur in the presence of water. By this heating process a combination is effected between the calcium and the sulfur, and sulfids of various compositions are formed. For practical purposes the color reactions are used as a guide. This spray applied

in the dormant period or just as the buds are swelling is effective against the scale insects and is also efficient as a fungicide. The lime-sulfur has very largely displaced other fungicides against leaf-curl of the peach. More recently the self-boiled lime-sulfur formula has been proposed. It promises to be effective upon peach trees in foliage. This is a much more dilute formula than the one used upon dormant trees; both are described in the spray calendar. Latterly, various dilutions of the lime-sulfur residues formed when lime and sulfur are boiled together, have come into use as sprays for orchard use.

SOLUTIONS FOR SEED TREATMENTS AND DISINFECTION:

FORMALDEHYDE SOLUTIONS

Formaldehyde in 40 percent solution is obtained upon the market. Solutions of this 40 percent compound in water are effective in seed and soil treatments and for disinfection. The following are standard strengths:

- For oats and wheat, 1 lb. or pint 40% formaldehyde to 40 or 50 gals. water.
- For potato scab and rosette, $\frac{1}{2}$ pint of formaldehyde to 15 gals. water.
- For onion smut, 1 lb. of formaldehyde to 25 or 33 $\frac{1}{2}$ gals. of water.
- For soil drench, 2 to 4 lbs. of formaldehyde to 50 gals. of water.

CORROSIVE SUBLIMATE SOLUTION

For treatment of potato tubers and for laboratory disinfection, mercuric chlorid, corrosive sublimate, is used as follows:

Corrosive sublimate	2 ounces.
Water	15 $\frac{1}{2}$ gallons.

GASEOUS DISINFECTION WITH FUNGICIDES

Latterly the methods used for the disinfection of houses where patients have suffered from contagious diseases such as diphtheria, scarlet fever, etc., have been extended to the treatment of plant diseases. The following formula of the Maine Board of Health is applicable to the details below given:

FORMALDEHYDE GAS

Commercial 40% formaldehyde	3 pounds.
Potassium permanganate crystals	23 ounces.
Sufficient for 1000 cu. ft. of space occupied by crates or trays.	

The following suggestions from the spray calendar of 1908 will be helpful to students or experimenters who have not access to other literature:

"Enclose open tiers or piles of slat crates filled with dry onions, potatoes, etc., in tight room or oiled tent of canvas buried in earth about the base. Generate the formaldehyde gas in a flat bottomed

dish or pan of adequate capacity by placing one of the materials, as the liquid formaldehyde, in the pan, and adding the other the last thing before retiring. Then close tight and allow to remain closed 24 to 48 hours.

Proportionate or multiple unit amounts may be taken for smaller or larger enclosed spaces. Applicable to fumigation of seed potatoes for scab, sweet potatoes for rot troubles and to newly gathered, dry onions before storing for winter.

For grain elevators to disinfect against conditions there or for mass treatment of seed oats and wheat a similar use is made of formaldehyde gas.

ROT DISEASE LOSSES IN STORAGE

No sharp line can be drawn between diseases of edible plant products which usually infect these crops previous to harvest, and the rots, molds or decays in such fruits and vegetables during storage. It has seemed best, for this reason, to insert here a brief discussion of these storage troubles which apply to products grown in our region. We can scarcely be called on to present the facts concerning the diseases of citrus fruits in storage or in transit.

All growers of fruits and vegetables in our state are liable, however, to have had losses from rots of fruits and vegetables during storage upon the farm. In the more recent custom of concentrating such storage products in cold storage plants, especially constructed for that purpose, the problem has only been transferred or transplanted: the difficulties have not been entirely overcome.

For the fruits known as perishable, namely, for peaches, plums, cherries and grapes, the custom of brief storage has become well established; the rots or other injuries, such as those that come from crushing, are well known. The storage rots are not different from those commonly found in the orchards—indeed, they are usually the common soft-rot of stone fruits, *Monilia fructigena*. Storage or transit losses from it are but an accentuation of orchard conditions. Also with the stone fruits, as a result of bruising and shipment, we have various of the common molds which develop on the bruised surfaces. The more usual ones are the common bread mold, *Mucor*, the blue mold, *Penicillium*, or the almost equally frequent form of green mold, *Aspergillus*. None of these, however, is likely to penetrate very deeply and be a serious enemy of these fruits. This arises, however, not so much out of the lack of ability to injure by these mold attacks, as from the very brief period of time which these tender skinned stone fruits are held before consumption. As has been pointed out by Powell and Smith, the

same common molds, including especially *Penicillium*, possibly with the aid of others, are sources of serious loss in the handling of citrus fruits—oranges, lemons, etc., during their prolonged periods of transit and storage.

In the case of grapes the losses are almost altogether due to breaking of the skin following which molds and bacteria are liable to appear under favorable conditions.

STORAGE ROTS OF APPLES AND PEARS

With apples the commonest storage rot for our district is doubtless also the commonest orchard rot, namely, black-rot, due to the black-rot fungus, *Sphaeropsis malorum* Berk. All are familiar with orchard conditions liable to prevail at ripening time. This fungus is generally found, especially in orchards of mixed varieties, because some sorts are commonly attacked by it. The same fungus causes cankers upon branches of the susceptible varieties and is usually well distributed over orchards. The punctures of worms or of bees, or wounds caused by mechanical injuries such as occur in wind-falls, and the various drops at picking time, afford easy entrance for the fungus. In consequence we must expect that the fruits which have been in any way punctured or injured, have also been exposed to infection by the black-rot fungus. Such infected fruits are very liable to rot because of the progress of the fungus, if conditions are favorable. The high temperatures of storage sheds and ordinary freight cars during October and early November in our climate, are such as favor its development.

In the light of our present knowledge the best we can do is to transfer fruit as soon as possible to storage where the temperatures are low enough to restrict the fungus. It follows without saying, that good results are obtained only from absolutely sound fruit, and the low temperatures of cold storage houses, 42 degrees or below, may be relied upon to check this rot to a very large extent, provided only sound fruits are placed in storage.

Naturally the discussion which follows under the storage of onions will raise the question here as to the practicability of gaseous disinfection of apples by the use of formaldehyde gas. It would seem possible under favorable weather conditions when fruit can be gathered dry and brought into storage houses in that condition, to disinfect the fruits by the formaldehyde gas method. Of course it follows that the period of disinfection will be brief in order that little or no gas will be absorbed by moist or exposed fruit surfaces, since formaldehyde is objectionable in foodstuffs. The time of fumigation may not need to be more than about half that used for potatoes or onions, and the strength of the formula may even be modified. The aim would be the destruction of external spores, etc., which certainly are a menace at all times.

The bitter-rot fungus, (*Glomerella rufomaculans* (Berk.) Von Schrenk) may also develop in storage apples where these have become attacked by it before harvest. The bitter-rot may be more common upon late summer and fall varieties in transit, than in ordinary winter storage. Certain sweet apples, such as Bentley Sweet, are very susceptible to bitter-rot losses in storage. Cold storage temperatures hold back the development of the fungus, but cannot disinfect the diseased fruits.

Pear rots with us are almost exclusively those which occur in the orchard. The leaf-spot fungus (*Entomosporium maculatum* Lev.) also attacks the fruits of pear and may become a source of loss in storage. This applies more particularly to inferior grades of fruit. Pacific coast fruit which is shipped to our district, may further suffer from some of the ordinary molds which find access to the fruit entirely through bruised or other injured areas.

The brief storage of quinces usually does not lead to much further development of the quince rot. The fungus in question is commonly the same as that in the apple rot, (*Sphaeropsis malorum* Berk.).

STORAGE ROTS OF POTATOES, ONIONS, ETC.

With vegetables we have a very wide range of storage troubles. In the case of potatoes we have two general types of rots, namely; wet-rot and dry-rot. The wet-rot of potatoes commonly results from two causes, viz.: The late blight or rot fungus (*Phytophthora infestans* D'By.) may be expected to cause considerable losses of the tubers in storage when these have been gathered from *Phytophthora* infested fields and bacteria may cause rot in injured tubers. In Ohio, as stated under this disease of potatoes, the late blight and rot fungus is not commonly prevalent. Perhaps little can be done to preserve the tubers from such fields except to market the crop promptly and to store with especial respect to the optimum conditions. The best temperatures for such potatoes will be warmer than for apples, and it is very desirable that moisture be kept as low as possible.

A wet-rot of potatoes, purely or very largely bacterial in cause, must also be dealt with. This rot bacterium is different from the bacterium of potato wilt, (*Bacillus solanacearum*) and without the latter may also induce considerable decay. It is believed the bacteria producing this wet-rot gain entrance through injuries to the tubers and that low humidity—dry storage—is especially desirable in keeping down losses from this source.

Dry-rot of potatoes is due to a fungus (*Fusarium oxysporum*) which appears to belong among our soil infesting fungi. This fungus appears to be the cause of premature dying of the potato plants and it certainly survives in the tubers from such infected plants. At harvest time, as shown under dry-rot of potato, tubers show infection at the stem end. Subsequently during storage the fungus penetrates more deeply into the tubers and will often produce dry-rot of the infected tubers. Further descriptive matter concerning dry rot will be found in the special part of the bulletin under potato. For storage of such infected tubers, as well as for the general crop, it is desirable that storage temperatures be kept about 42 degrees Fahr., or slightly lower.

Sweet potatoes also suffer from a large variety of rot troubles. These sweet potato rots are more or less special in character and since the crop is not largely handled in cold storage, nothing is here offered in addition to what appears in the special part of the bulletin

ONION ROTS IN STORAGE

Onion rots are a serious matter with onion growers and onion dealers as well. It has been found that particular varieties of onions in our climate are susceptible to special diseases. For this reason we must consider white onions such as White Silverskin, White King, etc., in a separate class from the rots of red and yellow onions such as the Globe and Wethersfield varieties.

With the white onions the problem is partly a field problem at harvest time, and partly one of storage. The growers are in the habit of gathering the white onions before the tops fall and topping them immediately, instead of throwing together in heaps for absorption of the substance of the tops by the onion bulbs as is practiced with the riper red and yellow varieties. After topping the white onions

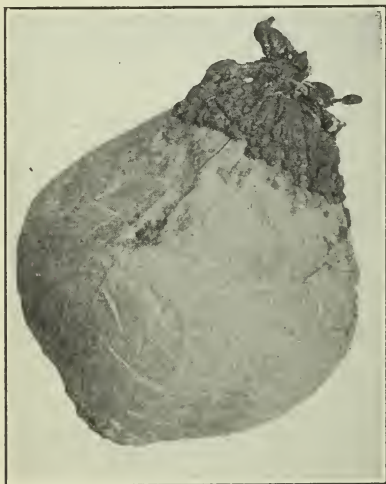


Fig. 27. A white onion that has been destroyed by a blackneck or dry-rot fungus, *Sclerotium cepivorum* Berk. This parasite has entered the onion through the green neck which was cut off at the time of harvesting the crop. (From a photograph by T. F. Manns).

are placed in slatted crates, and these crates are stacked in the field or in open sheds where they are kept dry. Often the loss from rot during the six weeks following harvest may reach 60 percent of the

crop, and as shown by investigations in Connecticut and our own state, it has not always been clear why these losses are so large. Recent investigations by this department lead us to believe that the green onion neck of white onions handled in this way affords entrance for the organism of the rot.

The sclerotium rot (*Sclerotium cepivorum*) appears to be the most serious, although smudge or anthracnose of the onion (*Vermicularia circinans*) may sometimes cause large losses. Both these rots are described under diseases of the onion. The writer believes the Sclerotium rot is the larger criminal, and that both may be handled by disinfection of the onions immediately after harvest. This disinfection may be carried out as described under the Maine formula for Formaldehyde gas treatment, which is:

Commercial 40 percent Formaldehyde..... 3 pounds.
Potassium Permanganate crystals..... 23 ounces.
Sufficient for 1000 cu. ft. of space occupied by crates or
trays. (See page 360).

The object of immediate disinfection is to prevent the entrance of these organisms, particularly the sclerotium rot, through the green neck of the newly topped onions. The exuding juices offer favorable culture conditions for the fungus to develop.

When no fumigation is practiced following harvest, the onions which are found to be sound and delivered for storage at the close of the season may very profitably be treated in this way before winter storage. Both these rots are essentially dry-rots of onions. In addition, sometimes, we have wet-rot of white onions which may be either due to bacteria or to the same fungus as the wet-rot of Globe or other onions mentioned below.

The rots of yellow and red onions are of both the wet-rot and dry-rot types, but the wet-rots are much more serious with these varieties. Doubtless, as in all vegetables held for a long time in storage, we have many cases of wet-rot in onions where some of the common decay bacteria are the chief cause. These find entrance through wounds, as in topping, and, under conditions favorable for their development invade the tissues of the onion and cause decay.

In addition however, to the wet-rots due to bacteria of undetermined species, we have a specific wet-rot of onions due to *Fusarium* species. This wet-rot fungus belongs to the same group as the potato dry-rot and is liable to infect soils in which onions are grown year after year. Rotted onions will show external developments of the pink fungus and may be detected in that way as well as by use of the microscope. The chief factors of control with onions of this kind, are in the methods of culture followed to produce the crop.

Dry-rot of red and yellow onions is rather rare and is commonly referable to the anthracnose or *Vermicularia* dry-rot fungus described under white onions. The best temperatures for onion storage are about 38 to 42 degrees.

SPECIAL PART II

DISEASES OF OHIO PLANTS. ARRANGED ALPHABETICALLY ACCORDING TO HOST PLANT

ALDER

Powdery Mildews. The alder suffers from several powdery mildew fungi on the leaves (*Phyllactinia suffulta* Sacc., *Erysiphe aggregata*, (Pk.) Farl., *Microsphaera alni* (DC.) Wint.) These retard development as with other leaf coverings. Alder may also suffer from two or three leaf infecting diseases such as an anthracnose and a leaf-spot. We have as yet little data concerning other occurrences owing to the neglect of the study.

Stem Blights. From England an interesting branch parasite (*Ditopella fusispora* De Not) has been reported by Plowright. This may or may not as yet occur with us.

Root Tubercles. These root developments on the alder and some other woody plants are commonly described as *Mycorrhiza*. The particular organism (*Frankia alni* Wor.) has attracted a good deal of attention from students of forest problems in Europe. Investigations of such growths upon the roots of our woody plants is very much needed at this time in Ohio.

ALFALFA--LUCERN

Anthracnose. Two new anthracnoses have been discovered attacking alfalfa; the first of these, *Colletotrichum trifolii* B&E, so far as we know occurring exclusively on plants of this family, the other, *Colletotrichum* sp., occurring only on alfalfa in northern Ohio. The first one, which we may call clover anthracnose, was discovered in Tennessee and has appeared upon alfalfa as well as red clover in the southern portion of Ohio. It is less prevalent on alfalfa than upon the red clover. Up to this time this disease has not been discovered upon either host in the northern half of the state. The second anthracnose occurred recently upon alfalfa from Sandusky and Carroll counties and has not been described. Both of these diseases show as a specific lesion or diseased spot on the stem or leaf-stalk in the advanced stages of attack. Following this the plants wilt or die and are discovered in this way. The disease is too new with us to measure its injuries directly. To the writer it appears less serious than the dodders or the root-rot troubles.

Bacterial Blight (Yellowing). A bacterial blight of alfalfa, of which the causal organism has not been definitely determined, has been reported from Colorado where it appears to be spreading. In 1907 and to a still greater extent in 1908, there was much complaint of general yellowing of leaves of second crop alfalfa in Ohio and adjoining states, even extending to North Carolina. The symptoms were general yellowing of this crop. With brighter, drier weather later the next succeeding crop was of normal color. Bacteria have been found by the Assistant Botanist in connection with this trouble in specimens from eight localities and from four different counties in Ohio during 1908 and 1909.

Downy Mildew. The downy mildew fungus (*Peronospora trifoliorum* D'By) has occurred in Colorado, and is very liable to occur in our state. No suggestions can yet be made as to its prevention

Leaf-Spot Fungus. This forage plant is grown in parts of Ohio. It is attacked by the leaf-spot fungus (*Pseudopeziza medicaginis* (Lib.) Sacc.) which is found upon both leaves and stem. The small dark spots produced by it are easily seen. In

attempts to produce alfalfa seed at this Station, the fungus has stripped the leaves and seed capsules before maturity. It is very likely to prevent success in growing this seed in Ohio, though it is much less injurious to the forage crop proper because of cutting at short intervals.

Root-Rot. The same parasitic fungus (*Fusarium roseum* Lk.=*Gibberella Saubinetii* (Mont.) Sacc.) which attacks wheat in the form of scab and also red clover, has been found killing out alfalfa at Wooster (See Bulletin 203). This fungus may survive in stubble fields where wheat and oats have been grown. It readily kills off the young seedlings of alfalfa and if the soil is not fully prepared for alfalfa seedlings, the root-rot may extend its work and further destroy the stand. At present nothing better is known than adequate dressings of lime, preferably raw limestone, for areas to be seeded, together with their proper enrichment. At this time warning is given as to the possible seriousness of this trouble in the future. While not specifically noted in America another root-rot fungus somewhat known on other crops (*Rhizoctonia*) has also been reported upon alfalfa from France. Another root-rot fungus (*Ozonium omnivorum* Shear) well known upon cotton, also attacks alfalfa in the southwest. I believe this is not known to occur in Ohio.

Rust. Alfalfa suffers from a rust fungus (*Uromyces striatus* Schroet) and while it may scarcely have appeared in Ohio, it is almost certain to do so in time. Like the similar leaf diseases of red clover, it may have rather small economic interest.

APPLE

Bitter-Rot or Anthracnose. In recent years this fungus (*Glomerella rufomaculans* (Berk.) Sp. and Von Schr.) has been investigated and its survival in the

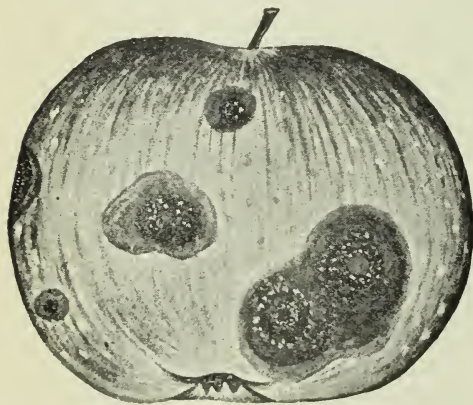


Fig. 29. An apple attacked by bitter-rot. A regular curved outline of the spores will be observed, the conidia of the fungus developing in concentric forms under suitable conditions. After Alwood.

mummy fruits and cankered branches proved. (Bulletin 40 Virginia Experiment Station; Bulletin 77, Illinois Experiment Station; Bulletin 40, Bureau of Plant Industry). This bitter-rot is also a ripe-rot, in common with other anthracnoses. For Ohio certain varieties are the chief sufferers; one of these is the Bentley Sweet grown in Belmont county, another is the Rambo. The disease develops in the later season and it seriously impairs both the eating and keeping qualities. For its control the destruction of mummy fruits and attention to branch cankers are necessary in addition to the application of sprays. Since we know the life history of the fungus better it has been possible

to control the bitter-rot successfully under orchard conditions as the annual sources of infection in mummy fruits and cankers have been mastered. In this late spraying soluble sprays are used toward the end as with the black-rot of the grape.

Black-Rot. The black-rot also at times called brown-rot, is apparently more common in the orchards toward the southern portion of the state. The writer has found it a serious matter to control the black-rot fungus (*Sphaeropsis malorum*

Pk.) which attacks both fruit and branches and is a bar to successful maturity of Northern Spy, Smith's Cider and some other varieties at certain times. It also invades storage apples and this rot is the most universal one in ordinary cellar storage. With varieties adapted to climatic conditions, methods of handling by sprays and destruction of cankers and mummy fruits should prove as effective as with bitter-rot. Unfortunately the varieties which most commonly suffer from black-rot are those growing beyond their safe range of conditions.

Brown-Rot. There is a rarer rot fungus (*Sclerotinia* (*Monilia*) *fructigena* (Pers.) Schrt.) than that of black-rot, which also attacks the apple in some parts of the United States. For our region it is little known on the apple and probably less important than either of the preceding.

Brown Spot or Dry-Rot of Baldwin. Very frequent complaint is made of small sunken spots in fine specimens of Baldwin and some other varieties. Internally these sunken spots are dry and somewhat bitter, leading to general breakdown of the apple. These spots have been referred to a particular fungus, (*Phyllachora pomigena* (Schw.) Sacc.) but the case is not proved. This internal brown spotting also occurs in Northern Spy and in Fameuse, and we hear complaint of losses from it. The causes of the internal spotting are probably the same in all cases and must in part be regarded as physiological breakdown. New Hampshire Experiment Station (Bulletin 45) succeeded in controlling the form of this dry-rot on Baldwin by the use of Bordeaux mixture. Some irregularity in results from spraying for it have been recorded elsewhere.

Canker. These diseased conditions upon branches may occur in the propagation of bitter-rot, but are more commonly referable to the black-rot fungus, (*Sphaeropsis malorum* Pk.) or to the blight bacterium (*Bacillus amylovorus* (Burr.) De Toni (See Bul. 163, N. Y. Experiment Station and Bulletin 235, Cornell Experiment Station) although other fungi are common in Europe as the cause of canker. Among these are species of *nectria*. Probably the canker due to the black-rot fungus must contest with that due to the blight bacterium for first place in Ohio, and its control is interwoven with the control of the black-rot on fruit. Canker-like dying of the external bark may, and sometimes does, occur without immediate penetration to the inner bark layer or injury to the branch. All these cankerous developments are, however, a source of danger and call for continuous watchfulness. The conditions of the fungus attacks are those of possible rifts in the outer bark followed by the localizing of the fungus development. Those for the blight canker are more extended and include blossom spurs. (See twig blight and pear blight). It seems probable also that the power of resisting attack varies with the vigor of the branches. Up to this time our remedies have been largely



Fig. 29. Apple branches attacked by canker.

the general ones of germicide sprays with addition of scraping off loosened bark where possible; for this purpose a dull tool is preferable. Some forms which might be called canker on young trunks and on older branches are in fact forms of winter injury from freezing. Types of branch cankers are somewhat variable, but they are all matters calling for close attention.

Collar-Rot. (See Sun-Scald).

Coryneum or Orange Leaf-spot. During 1908 and 1909 specimens of an orange leaf-spot have been received, and a severe case of defoliation of apple trees in town was reported from Stark county. This leaf-spot is a central, erumpent pustule with an immediate border of orange yellow: this yellow area shades off into dark color toward the green tissue. Hartley has reported, upon investigations of the fungus in this case, *Coryneum follicolum*, that it is not actively parasitic. Possibly we have this fungus following something else, after the manner that another fungus follows the black-rot leaf-spot described below. (See also rust of apple).

Crown Gall. This disease is especially a nursery trouble of apple and shows its effects by enlargements near the crown or upon other portions of the stem or root. It is quite probably due to the same organism (*Bacterium tumefaciens* Erw Sm & Towns) as the olive knot or some other crown gall troubles. This is decidedly an infectious disease which probably calls for inspection of nursery stock, and for great care to provide against diseased trees. Cure of infected plants has not been secured. There is great danger in endeavoring to grow nursery stock upon land which was once infected with the organism.

Edema. An Edema or swelling of apple twigs has been described by Atkinson from New York (Cornell Station, Bulletin 61). This on closely trimmed trees on over fertile soil.

Fly-speck Fungus (*Leptothyrium pomi* (Mont. & Fr.) Sacc.) This obvious fungus disease in ordinary seasons appears chiefly upon apples grown in low,

moist situations. Peck's Pleasant, Rhode Island Greening, Rome Beauty and several other varieties have been noted as affected by the Sooty Fly-speck troubles which may be identical as to cause. During wet seasons, like that of 1896 and 1909, a few susceptible varieties are liable to be spotted by this parasite whatever be the location of the trees. Aside from selecting high, sunny situations for the apple orchard, spraying with Bordeaux mixture will prevent this spot. (See Sooty Fungus).

Fruit Blotch. Fruit blotch is a recently described fungus (*Phyllosticta solitaria*, E.&E.) which causes a serious spotting of fruit in a number of ways as described in bulletins of the Illinois and West Virginia Experiment Stations, so that we may expect it to give trouble in Ohio. As indicated the fruit is attacked by this spotting

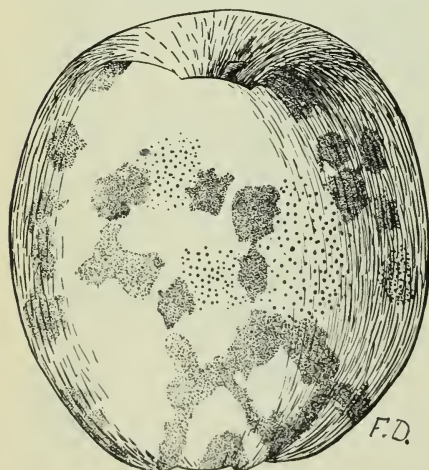


Fig. 30. An apple attacked by the Fly-speck fungus. The sooty fungus is also abundant on specimen as is usually the case.

and in addition the fungus produces small cankers on twigs. Scott has recently shown that it will be fully controlled by three or four sprayings with Standard Bordeaux mixture. (See Bulletin Bureau of Plant Industry).

Leaf-spot or Frog-eye. There is a common leaf-spot disease of apple trees in which the dead spots show the presence of pycnidia. This trouble is really due to the black-rot fungus (*Sphaeropsis malorum* Pk.) but at times another fungus, (*Coniothyrium pirini* Sacc.), comes in afterwards. In the later season the second type develops in concentric areas to which the common name of "Frog Eye" has been given. Yet other forms of leaf-spot due to spray injuries also occur, but are easily distinguishable from the two first named. It has been shown that control of the black-rot fungus keeps the leaf-spot in hand, but early treatments should be made.

Mold. A blue mold is very commonly associated with soft rot of apples in storage. The fungus (*Penicillium glaucum* Lk.) is a very common one and may be regarded as associated with the presence of decay or bruising, not as a first cause of rot.

Mildew. The powdery mildew (*Sphaerotheca mali* (Duby) Burr.) often occurs upon nursery growths of the apple and occasionally upon rather thrifty growing young trees. The dense felt-like covering of the fungus is usually very apparent and the spreading of the fungus upon the foliage is sometimes noticeable. Spraying with fungicides usually keeps the trouble in check.

Rust. The bright orange growths of this rust fungus (*Gymnosporangium macropus* Lk., etc., I) are occasionally found on cultivated apple leaves as well as on leaves of wild thorn apples, especially where these are within reach of the cedar trees which bear the cedar apples. In 1909 the rust attacked apple fruits in Ohio and Nebraska. These so-called cedar apples are no more than the development of the rust fungus from which the spores are spread to the apple, *Crataegus*, etc. A remedy is indicated by this statement, viz., get rid of cedar trees.

Root-Rot. Serious root-rot troubles have been reported to us from Missouri, Arkansas and Oklahoma where orchard plantings have been made quite soon following the clearing of scrub oak, etc. Similar cases have been studied in Ohio where plantings were made soon after the removal of the timber, especially of oaks. One is usually able to identify the rhizomorphs of the root-rot fungus, (*Agaricus melleus* L. (*Armillaria mellea*)) and the characters by the occurrence upon orchard trees and also the original growth is usually quite clear. Any inadequacy of drainage is very serious in connection with root-rot. (See root-rot of peach, etc.). More recently Von Schrenck has identified another fungus (*Thelephora galactinia* Fr.) with a form of root-rot which shows no superficial symptoms until after the tree is dead; it then shows the orange, leathery sheets.

Scab. Apple scab fungus (*Venturia inequalis* Aderh, *Fusicladium dendriticum* (Wallr.) Fuckl.) is a common source of large losses in Ohio apple orchards. It attacks first the leaves and afterwards the young fruit, causing it to drop. Aside from injuring the salability of the crop obtained and reducing the vigor of the tree by reason of its attacks on the foliage, *scab may prevent a crop altogether because of this dropping of the young apples*. The Ohio Station was in the van of progress in studying this disease, and the work has been steadily followed (Bulletin Vol. IV, No. 9, (1891) B. 79, (1897) B. 111, (1899). Full details may be found in the various bulletins given. Apple scab develops when moisture is abundant during the early months of the season, and low temperatures are usually prevalent at such times. The dropping of apples often attributed to lack of pollination seems more often to be ascribed to the work of scab. All varieties are attacked by scab but some suffer more than others.

The profit from spraying for scab on the apple (including apple worms) has generally been large, because of saving the amount of crop and enhancing its market value at the same time, as well as increasing the number of crops. In this way the crops of a single orchard have been sold for a gain of about \$1000 on an expenditure of \$125 to \$150. At the Station this gain has amounted to \$5.00 per tree (B. 111). The best fungicide for this purpose is dilute Bordeaux mixture, or Bordeaux I of the spray calendar, containing 4 pounds of sulfate of copper and 4 pounds of quicklime to 50 gallons of mixture with water, or Bordeaux mixture and Iron Sticker consisting of 2 pounds of copper sulfate, and 2 or 3 pounds of iron sulfate in 50 gallons of water. The Bordeaux mixture and Iron Sticker has given better results in a rainy season like 1909. The first spraying should be made just before the blossoms open, and upon the young leaves, and the second after the blossoms drop, with additions of arsenites in the second and in a possible fourth spraying as stated in the spray calendar.



Fig. 31. Young apples attacked by the scab fungus (*Venturia inequalis* Aderh).

Scurf. The branch scurf fungus (*Phyllosticta prunicola* Sacc.) is believed to occur in Ohio. This causes roughening of the bark, but no statements can now be made as to its possible seriousness.

Sooty Fungus. The sooty fungus (*Phyllachora pomigena* Schw.) is often associated with the fly-speck fungus, previously described, and is the more unsightly trouble of the two. In most seasons the fruit in low situations is

liable to be rendered unsightly and unsalable by the spots which are illustrated in Fig. 32. In seasons like that of 1909 the disease may appear on unsprayed trees in practically all situations. It was found in comparative tests of Bordeaux mixtures and self-boiled lime-sulfur for apple scab and other fungi, at the Carpenter test farm, that the sooty fungus appeared on the fruit on the lime-sulfur trees. It is thought by several that this fungus spreads upon the fruit after it is stored and at whatever time it appears it renders apples dull, unsightly and unsalable. Bordeaux mixture or its modifications may be relied upon to hold the fungus in check. One spraying at the time the apples are the size of hickory nuts may prevent nearly all of the injury. Upon varieties like Maiden's Blush, Grimes and Belmont the spraying should be done a little earlier than just stated. The demonstrations by the Station all over the state, show clearly what improvement the spraying makes in the apples where this trouble prevails.

Sun-Scald, Collar-Rot. There is frequent complaint of the dying of the trunk of both younger and older apple trees wherein there appears to be associated the exposure to sun and the death of the bark of the trunk upon younger orchard trees. The freezing injury has been carefully worked out in recent years and is discussed under winter injuries, with several varieties of apples, notably the Grimes and King this trouble is so serious over much of Ohio as to reduce the growth of these sorts; while Murrill has suggested a connection between a fleshy fungus and this dying of the trunks of the King the connection has not been proved. The injuries which occur on the south and southwest exposures of the trunk have probably a direct connection with the danger from freezing injuries. Some apparent sun-scald is more probably due to the bacterium of pear blight as has been recently proved by cultures from young trees by Waite. With Grimes and other varieties susceptible to collar-rot caused by the bacterium of pear blight the only true relief is found by top working on some vigorous sort such as Baldwin, Gano, and like varieties. In the case of true

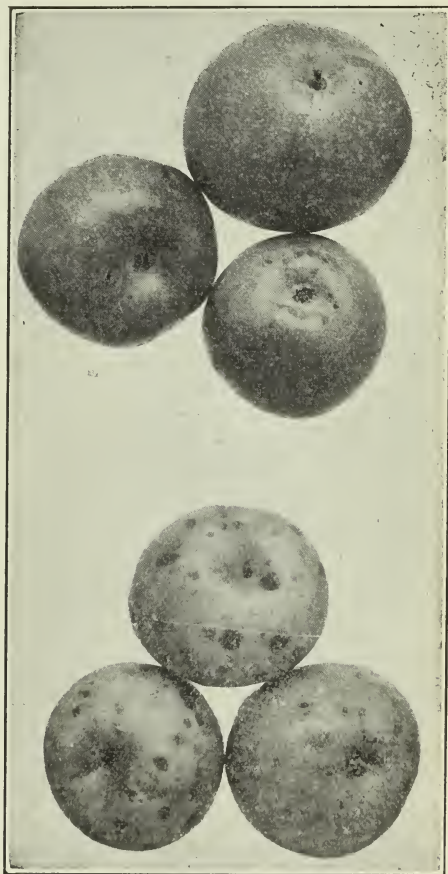


Fig. 32. Apples spotted by sooty fungus. The apples shown above were sprayed with Bordeaux mixture followed by two sprays of Bordeaux and Iron Sticker. The apples shown below were sprayed first with Bordeaux mixture and this was followed by two sprays of self-boiled lime-sulfur. In neither case was the scab entirely prevented. The lime-sulfur spray was not strong enough to keep off late attacks of sooty fungus. From a photograph by T. F. Manns.

sun-scald the effect of freezing is to form an ice layer and thus separate the bark or in the case of many water gorged cells to kill the sap layer. For further discussion in this line see winter injury.

Storage Rots. These rots of the apple are extremely various since apples infected before storage are liable to develop during storage the forms of rot due to that infection. Even bitter-rot may not be overlooked in this way and much more commonly still, black-rot and the rots which develop from the gradual invasion of molds. It is found, furthermore, that bruises upon the apple or any tendency to sun scald phenomena give dead tissues in which various saprophytic organisms that normally hasten decay will do their work with rapidity. It is understood, of course, that the temperatures of storage will regulate or control more or less perfectly the rate of this development. Storage scalding of apples is much worse in some varieties, notably in York Imperial than in the normal toughened skin types. At present one can only suggest the rejection of those sorts susceptible to scald for cold storage keeping.

Twig-Blight. This disease of the apple, caused by the bacterium of pear blight (*Bacillus amylovorus* Burr.), is often very prevalent. The microbe enters through the blossoms, being propagated in the nectar after infection by insect visitation. It destroys the blossoms as well as small twigs of the tree. Beyond the injuries just noted this microbe may gain entrance through the bark. (See sun-scald). The twig injury is not very great from this cause on the apple, though the small dead twigs are unsightly. The prevention will lie in the destruction of all the blighted parts on apple, crabapple, pear and quince trees in the vicinity. For fuller discussion see pear blight. In substance, this treatment consists in cutting out all blighted portions in fall and early winter and burning them to kill the resting forms of the microbe. It seems further that well timed, early spring spray treatments on pear, etc., will cover up or destroy spores of the blight. (See Circular 87).

Water Core. With the so-called Russian apples and occasionally with other varieties as Yellow Transparent and Early Harvest, there are water core conditions, at times, which may result in subsequent rotting. No explanation is here offered as to cause for the condition.

Winter Injury (also called Sun-Scald). As previously mentioned there are a number of evidences of injury which involve the trunks of apple trees of all sizes; they are many times due to freezing injury; while this name winter injury appears at the beginning of the paragraph and while the name sun-scald has been applied for a long time to similar conditions, the injuries are directly due to freezing, sometimes occurring in winter and sometimes, as in October 1906, due to premature low temperatures. A conspicuous case occurred in the fall and winter of 1906-7, more fully described in the bulletin devoted to these injuries (Bulletin 192). At that time as in other cases of injury from freezing, the low temperatures occurred when the trees were gorged with water (sap). In the fall of 1906 we had very heavy rainfall with low temperatures so that there was stimulus to excessive water absorption and no tendency to hasten ripening of tissues through water loss and reduced water content such as occur in dry autumn periods. The losses of young trees set one to three years, were very large in the winter of 1906; indeed, in some cases there was practically a total loss as on slow growing varieties, notably the Rome Beauty in the Station plantation at Carpenter. In general at that time the typical late variety of the northern part of the state, Baldwin, and of the southern portion, Rome Beauty and the Hubbardson were most seriously injured. It is evident that where we have such excessive water supply in the inner bark and in the process of freezing, a layer of ice crystals

is formed. There is great danger of separation of the bark layer from the wood at that time as at others. The sun exposed side seemed to have suffered worse by reason of the more extreme temperature changes which were incited on these exposures. It is evident that warm periods in winter are a source of danger when followed by low temperatures.

Upon very large trunks near the base, as on Grimes and some others, this may be the real explanation of frequent sunscald or basal injuries. Wherever such an injury begins there is risk of the intrusion of wound fungi with all the consequences which follow their entrance. The handling of winter injuries must so far as prevention goes precede the conditions which cause it. Where possible the prevention of excessive late growth is desirable. In cases of orchard trees it may be that mulches of coarse litter, especially, will prove serviceable. It may be added that this injury to woody growths is a less developed phase of the killing back of herbaceous plants by the premature frosts.

Another phase still is the killing back of branches at the tips of woody growth which are not strictly hardy in our climate. In the case of our Japanese plum and of some ornamental shrubs, this is a frequent phenomenon and its cause is to be sought in the same factors above described. Growth being protracted late in the season, these water gorged terminal twigs are killed by the subsequent winter freezing whenever this is severe.



Fig. 33. Jonathan tree, 4 years old, Southeastern test farm, Carpenter, in cultivated portion. Tree of vigorous previous growth with small lesion near base of trunk caused by freezing and sprouts from below. Photographed July 20, 1908. From Bulletin 192.

APRICOT

The apricot is rarely planted though occasionally is set in our Lake Districts. The chief difficulties there have been the tendency to kill back in winter. Apricot foliage in addition is liable to be attacked by the similar leaf parasites of peach and plum.

ASH

Trunk Rots. The ash as a forest and shade tree is a vigorous grower, but it is often marked by the attacks of timber decays where these enter through wounds or by means of the bases of dead branches. We have urgent need for more knowledge of these wound parasites.

Leaf-Spots and Rust. I may also state that the foliage of the ash is attacked by rust (*Puccinia fraxinata* (Lk.) Arth.) but in the present state of our knowledge we are unable to apply effective remedies. This rust, as in the case of other rusts, shows by the presence of its reddish or brown colored spore masses. Of leaf-spot fungi there are a number which call for careful study.

ASPARAGUS

Anthracnose. An anthracnose fungus of asparagus (*Colletotrichum* sp.) is known in New Jersey but has not been frequent, if present, in Ohio.

Rust. In the east and in Europe the rust of asparagus (*Puccinia Asparagi* DC.) proves to be destructive, and it has finally spread over Ohio.



Fig. 34. Asparagus attacked by rust. The rust causes elongated development of the fungus, both upon the stems and leaves of the plant.

The rust causes appearance of unusually early maturing of the plants. Closely examined the rusted plants show blister-like spots on skin of the stem, and underneath these ruptures there is brown color due to the spores. The rust also assumes another form, the cluster-cup stage, which may be found in early spring with different color on volunteer plants; indeed the aecidial, or cluster-cup, uredo and teleuto-spore stages succeed each other on the stem. The usual recommendations are to burn the rusted bushes in autumn and to spray with Bordeaux mixture; this latter "reduces the amount of rust about one quarter." (N. J., B. 129). The Leopard spot of asparagus stems is apparently not infrequent, and the anthracnose of asparagus, which produces very small specks upon the stem, may also be expected, yet neither of these compares with the rust in destructiveness, nor does the rust of any other plant appear to surpass this in its ravages. The Palmetto variety is reported less susceptible to rust than any other sort.

AZALEA

Leaf-Spots. This plant is grown as an ornamental plant and whether in hothouses or in protected planting out doors, is liable to injuries from leaf diseases. One of these is a leaf-spot fungus (*Septoria azaleae*). It is also liable to attack by a "bladders" fungus upon the young parts.

BARBERRY

Rust. The rust upon the barberry bush (*Aecidium Berberidis* Gmel.) is but a form or stage, the aecidial or cluster cups, of the wheat rust (*Puccinia graminis* P. *rubigo-vera* etc.). The increase of virulence in the rust of wheat and rye, when grown near barberry bushes, was long noted before the demonstrated

alternation of the fungus from the barberry to the wheat was proved in our century by DeBary. The barberry hedge is objected to, at times, by adjacent wheat growers, although we continue to suffer from the ravages of wheat rust many miles from any barberry bushes. In the absence of barberry the rust survives without it.

BARLEY

Rust. In the west and northwest there are two forms of rust; leaf rust (*Puccinia simplex* (Koern.) Erikss. and Henn.) and stem rust (*Puccinia graminis* Pers.). These rusts, like those of the other cereals, have not yet been mastered or controlled.

Scab. Barley is attacked by scab (*Fusarium roseum* Lk.) in a manner similar to that which occurs on wheat and rye. That the scab fungus is the same for all grains has been shown by recent work of this department. (See Bulletin 203).

Seed treatment for the loose spores and seed recleaning to get out the shrunk and scab infested kernels ought to give favorable results. (See wheat scab).

Smuts. The covered barley smut (*Ustilago hordei* (Pers) Kell. & Sw.) as well as the naked barley smut (*Ustilago nuda* (Jens.) Kell. & Sw.) both occur in Ohio, although barley is grown less extensively with us than in the west and northwest. In the covered barley smut, the smutted heads more commonly remain enclosed by the upper leaf sheath and a membrane holds the smut masses, while the spores are exposed and freely scattered in the naked barley smut.

The modified hot water treatment for loose smut of wheat has been found effective upon the barley smuts. See Farmers' Bulletin No. 75, Yearbook U. S. D. A., 1894. Spray Calendar, Bulletin 199.

BEAN

Anthraxnose. The anthraxnose of the bean causes unsightly spotting of both pods and growing organs and is referred to the anthraxnose fungus (*Colletotrichum Lagénarium* (Pass.) Hals.). This species is also regarded as the same one that attacks cucurbits, including cucumbers, watermelons, muskmelons and gourds. The spotting of the bean pods is looked upon, too commonly, as a natural phenomenon. Measures looking to its prevention have not found ready application by growers. That fungicides are effective in reducing it we have reliable testimony (N. J. Exp. Sta. B. 108). The recommended treatment begins by soaking the seed 1 to 2 hours in ammoniacal copper carbonate, 1 ounce of copper carbonate to 1½ gallons of water. Bordeaux mixture is to be sprayed upon 2 and 3 inch plants, followed by the same 10 days later, and again repeated after blossoming of plant. The great thing to remember is that this is a seed infecting disease. We must grow disease-free seed. (See Pea).

Bacterial Spot. A bacterial blight has been reported from New York (N. Y. Exp. Sta. B. 181) and New Jersey (Exp. Sta. Rept. 1892) which promises more or less injury. In this malady the diseased parts, leaves, pods, etc., show characteristic, often watery spots. It is less prevalent on fresh land. The organism (*Bacterium phaseoli* Erw. Sw.) is widespread.

Downy Mildew. This fungus (*Phytophthora Phaseoli* Thaxter), so far as known at present, has not been found in Ohio, though occurring to a destructive extent in the east, and liable to occur in our vegetable gardens. Experiments have shown that it is controlled by spraying with Bordeaux mixture.

(Conn. Exp. Sta. R. 1897, Pt. III). In this instance, as with the downy mildew of cucumber, it is probable that August 1 is sufficiently early to begin the application of the fungicides.

Powdery Mildew. Powdery mildew of the bean is due to the same fungus as the powdery mildew of pea, for which see pea.

Rust. This fungus (*Uromyces appendiculatus* (P.) Lev.) is often observed to produce reddish brown spore masses upon both surfaces of the leaves of beans. It is perhaps rather more variable in occurrence, and certainly less injurious in the past than bean anthracnose. It has been quite common in Ohio. Beyond burning diseased refuse we are not prepared to suggest remedial or preventive measures.

Stem-Rot. The root-rot fungus (*Rhizoctonia*) attacks the bean root and stem and at times spots the pods in the south.

BEECH

Anthracnose. The anthracnose fungus (*Gloeosporium Fagi* (Rob.) of beech attacks the leaves, but is not so serious as many of the other anthracnoses.

Leaf Diseases. While the beech is not largely planted, it is nevertheless a useful shade tree. The leaves are often attacked by two or three mildews (*Microrosphaera erineophila* Pk. & *M. penicillata* (Wallr.), also *Phyllactinia suffulta*), which, however, rarely gives serious injury to foliage. In Europe the beech is attacked by a rust fungus (*Melampsora Fagi*); the leaves are also attacked by a leaf-spot species of *Phyllosticta*.

BIRCH

Anthracnose. The anthracnose fungus of birch (*Gloeosporium Betularum*, E&M) attacks the leaves of our American birches while other anthracnoses are known on the European species. Our knowledge of the injury is very limited.

Mildews. The downy mildews of beech and alder in part occur upon the birches.

Wound Fungi. Characteristic fleshy fungi invade pruning or other wounds in the birch and are to be guarded against as with other woody growths.

BEEF

Leaf-Spot. The garden beet is quite liable to the attacks of the leaf-spot fungus (*Cercospora beticola* Sacc.) which causes serious impairment of leaf action and premature dropping of the foliage. Other changes are likely to follow those stated. This trouble may be controlled by the use of Bordeaux mixture at fortnightly intervals. (B. 199). The leaves of beets are also attacked by a white mold (*Cystopus Bliti* (Biv.) Lev.) although this latter fungus is less frequent and less ruinous than leaf-spot. The same fungicide may be used if required. See "sugar beet" for other diseases.

Scab. The scab troubles on the beet are similar to those on the potato and are referred to the same fungus. This trouble is likely to follow where beets follow in soil that has been diseased with either beets or potatoes.

Root-Rot. (See sugar beet).

BEGONIA. (See Pelargonium).

Nematodes. These minute worm parasites attack the roots and also the leaves of cultivated begonias (Ohio Exp. Sta. B. 73; N. J. Exp. Sta. Rept. 1894). For the commoner root injury avoidance is to be sought in the preparation of the earth.

Root-Rot. The root-rot fungus of violets and tobacco *Thielavia basicola* Zopf.) was found attacking the roots of begonia which suffered from nematodes. Its general occurrence since the discovery upon tobacco and catalpa show that it is capable of serious injury to the roots of these cultivated plants.

BLACKBERRY

Anthracnose. The anthracnoses of blackberry and raspberry (*Colletotrichum venetum* Speg.) are identical and are described under the raspberry.

Leaf-Spot. This disease is also common to the blackberry and the raspberry, although the latter is less commonly attacked. This fungus (*Septoria Rubi* West) is conspicuous upon the wild growth and upon the trailing dewberries; it produces, usually, small, light-gray spots in the leaves and yields to treatment with the standard fungicides. (See Ohio Exp. Sta. B. IV, 6, and B. 79).

Crown Gall. Is apparently of a similar contagious nature to that of the raspberry. It is of like appearance, though the galls at the crown of the plant are often larger. A plant once attacked is incurable, and offshoots from it appear to be generally affected, thus calling for immediate digging and burning of all the diseased canes and the abandonment of propagation from such plantations. (See raspberry crown gall).

Red Rust or Bramble Rust (*Caeoma nilens* Schw.) is a well known disease of the wild and cultivated blackberries, which also attack raspberries. It causes the affected leaves to turn first yellowish in color, remain erect in position, and finally to become bright red with an abundant coating of the spores of the rust fungus. These spores are readily scattered and may thus affect previously healthy plants. The threads of the rust fungus (mycelium) live year after year in the affected plants. For this reason the only remedy is to dig and burn all members of the rusted stools. (See Bulletin 79).

Root Diseases. Recent examinations of blackberry plantations show root diseases of undetermined cause. The affected roots show brown spots as if parasitized and the growth is seriously curtailed. Recent conditions in blackberry plantations indicate root parasites since sections of the roots become discolored and the growth of the canes is checked. These have not been sufficiently investigated for exact determination at this time.

BLUE-GRASS

Anthracnose. In the summer of 1908 the anthracnose fungus of wheat, rye, oats and other grasses (*Colletotrichum cereale* Manns) was discovered on blue-grass in Ohio. This shows as black spots on the stems and basal sheaths, and will evidently survive on this pasture grass. The injury is greater upon wheat, rye, oats and clover, under which illustrations are given, than upon blue-grass.

Bacterial Blight of Head. In a recent bulletin from this department (No. 210), Manns has described the organisms of blade blight in oats and has reported a head blight in blue-grass and timothy caused by them. In this case the bacteria appears to enter the upper sheath and cause a lesion above the upper joint. This ends in the death and the drying up of the heads.

Powdery Mildew. The foliage of the blue-grass is attacked by the conidial stage of the wheat mildew (*Erysiphe graminis* DC). This fungus gives little evidence of injury, though its presence is certainly *not* beneficial and the perithecia of the parasite are not common on this host.

Rust. Blue-grass is likewise attacked by a rust (*Puccinia graminis*) which is general on grasses.

Smuts. A smut fungus (*Ustilago striaeformis* West.) attacks the blades of blue-grass though it is possibly not often very injurious.

BROOM-CORN

Smuts. Of these there are two, head smut (*Ustilago Reiliana* Kuhn.) and grain smut (*Cintractia Sorghi-vulgaris* (Tul.) Clinton), the latter of which is prevented by treating seed for 15 minutes in hot water at 135 degrees F. and drying

for planting as for oats. The same smuts attack sorghum and are very likely to occur in foreign seed. (See Kansas Experiment Station Bulletin 23; Ills., Bulletin 47).

BUCKWHEAT

Leaf-Blight. This well known plant is frequently attacked by a leaf-blight fungus (*Ramularia rufo-maculans* Pk.) which produces whitened areas on the under leaf surfaces and causes dying of these leaves. It is not known to be sufficiently destructive to warrant treatment for prevention.

Another leaf trouble referred to a fungus (*Fusicladium fagopyri*) is reported from Europe, but is not known in our climate.

CABBAGE-CAULIFLOWER

Brown- or Black-Rot is a serious disease of these two crucifers, and attacks others of the family, including turnips. It is a veritable scourge to the cabbage growers of Ohio and other states. Smith (Farmers' Bul. 68, U. S. D. A.) has published concerning it and has attributed the disease to a specific germ (*Bacterium campestre* (Pam.) Erw. Sm.). The diseased heads may be dwarfed, in portions rotted, and brown colors will appear in the woody layers of the plant, including the stem. Badly diseased heads emit a penetrating and offensive odor.



Fig. 35. Young cabbages partially affected with club-root. The club-root survives in the soil and causes swellings and abnormal forms of the roots. After Halsted, Bul. 98, N. J. Exp. Sta.

The losses from the brown-rot have been very large and specific remedies cannot be stated. The author quoted sums up the subject of treatment in one word—prevention. The measures recommended are—plant on new land and only from healthy seed beds; avoid succession of the same crops; avoid stable manure and give preference to artificial fertilizers to escape possible infection through the manure. Prevent animals from cropping in diseased fields. Clean tools by scouring bright after use in infected soil. Fight the cabbage insects, since these inoculate healthy plants with the disease. Removal of badly affected plants, or newly infected leaves, at intervals, and subsequent burning or deep pitting of this refuse may aid in checking brown-rot. Destroy all mustard weeds. See page 318 for part played by water pores in the infection.

Club-Root. Club-root fungus (*Plasmodiophora Brassicae* Wor.) attacks these plants as well as the turnip, rutabaga, wild shepherd's purse, hedge-mustard and certain other plants of the mustard family. It is called finger and toe disease in England. It causes enlargement of the roots and prevents growth of normal head or root. (See figure, p. 380).

This fungus is harbored in the soil, so that if the land is once infected the disease may prove lasting. It has not yet been learned how long the trouble will survive if the soil is planted in other crops. Lands newly brought under cultivation may be infected with club-root through the wild mustard plants upon them. It would appear possible by watchfulness to avoid getting the club-root fungus into cabbage lands; the seed bed should be most carefully guarded from this trouble as from rot. It will be much cheaper to abandon the crop for some other, when the plant bed has become affected with club-root and the seedlings have enlarged or whitened roots from this disease.

In New Jersey, Halsted has investigated this trouble and has found (N. J. Exp. Sta. B. 98 and 108) that fresh stone lime, if applied at the rate of 75 to 80 bushels per acre upon freshly plowed land in spring, and worked into soil, will very greatly reduce the amount of club-root on turnips and cabbage; there is no reason to doubt that this treatment is applicable to all plants of the order attacked by club-root.

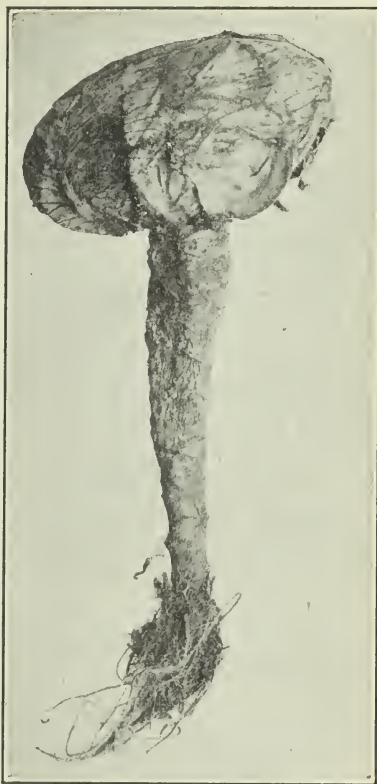


Fig. 36. Cabbage plant attacked by *Fusarium* wilt. This has caused the leaves to yellow and drop and the plant has produced no marketable heads. The lesion caused by wilt fungus may be observed upon the left-hand side, upper half of stem. From a photograph by T. F. Manns,

Downy Mildew (*Peronospora parasitica* DeBy.), Leaf-Blight (*Macrosporium Brassicae* Berk.) and White Rust (*Cystopus candidus* (P.) Lev.), occur upon the mustard plants, including, perhaps, all named above and some others. As yet their presence has not proved a serious drawback. If to be treated, Bordeaux mixture should be applied.

Wilt. The fusarium wilt disease earlier reported from the eastern truck districts, is now very destructive in Ohio. In 1909 it locally destroyed nearly all the crop where either infected plants were set upon fresh soil or plants were set on infected soil. It causes a yellowing and wilting of the plants sometimes with apparent stem injury. In our cabbage districts it may be this wilt is to contest with black-rot for first place in rank of injury done. The remedy lies in breeding wilt resistant strains of cabbage.

CALLA

A Root-Rot of callas has been studied by Halsted and Townsend. The disease appears to be due to bacteria (N. J. Rept. 1893). Reject rotted roots.

CARNATION

Bacteriosis of carnations has been reported upon by Arthur and Bolley (Ind. Exp. Sta. B. 59). This causes many small, brownish spots with yellowing of the leaves of the affected plants. Such are feeble in growth and deficient in return. The maintenance of best and most favorable growth conditions may often be effective in preventing this trouble; particularly sub-irrigation and war on aphides are to be recommended.

Bud-Rot. A serious rot of carnation (*Sporotrichum antrophilum* Pk.) is reported from several states and is doubtless present in Ohio.

Leaf and Calyx Mold (*Heterosporium echinulatum* (B.) Cke.) (Fairy Ring) of carnations is often very unsightly upon the calyces and pedicels of these flowers; it also attacks the leaves. All sorts appear to be more or less parasitized with the fungus in the houses where it prevails. Yet another spotting is produced by the carnation leaf-spot fungus (*Septoria Dianthi* Desm.), which has appeared at this Station more frequently upon the Daybreak variety. It is believed that both these fungi will yield to treatment with Bordeaux mixture as per calendar. (See Bulletin 73).

Carnation Rust (*Uromyces caryophyllinus* (Schrk.) Schroet.). This rust fungus is one of the serious diseases of the carnation. There is some difference in the liability of varieties to the disease, and perhaps a much larger difference in the condition of the stock plants from which cuttings are made. Assuredly this matter of "cutting stock" is of very great importance and one admitting of selection of the very best plants. Experiments conducted at this Station in 1896 by the writer and the Station Florist (See B. 73) yielded no gain from spraying with Fowler's solution, which has been sometimes recommended. Watchfulness in the destruction of rusted parts, and in the stock for propagation, are suggested for the control of rust.

A Root- or Stem-Rot (*Rhizoctonia* and *Fusarium*) of carnations has been noted by Stewart (Bot. Gaz. XXVII, 129, 130) and occasional rotting of the flowers through the presence of a Botrytis. For the former no thoroughly effective remedy is now at hand, while general cleanliness of the house is necessary to avoid the rot fungus Botrytis. (See Lettuce Rot).

CANNA

Rust. Foliage of canna is sometimes attacked by a rust which may be identified by the characters of its fungus (*Uredo cannae*).

CANTALOUPE

See Muskmelon.

CARROT

Leaf-Spot. This spotting of carrot leaves is usually caused by the same fungus (*Cercospora Apii* Fres.) as the celery leaf-spot. Upon the carrot the trouble is not usually serious.

CEDAR

Cedar Apples or Cedar Rust. During the showers of April, May or June, large or small, jelly-like masses, often one inch or more across, with firmer wood-like centers, are frequent upon red cedar trees and upon similar related plants. Microscopic examinations of these jelly masses show that they contain the spores of a rust fungus (*Gymnosporangium macrospus* Lk. and other species of *Gymnosporangium*). This fact need not startle us but for another, namely, that this is the completed or teleutospore stage of a rust which may seriously injure the leaves of the apple. The apple grower will run some risk then, in having about him diseased cedar trees. The remedy lies in the destruction of the cedar trees.

CATALPA

Leaf Blight. Leaf blight of catalpa has recently been troublesome to growers and puzzling to the Pathologist at times. The sudden blackening and dying of the leaves in early summer has been traced to frost, but other times in later summer to root-rot, which see. Frequently we have found a leaf blight fungus (*Alternaria* sp.) which developed freely upon the spotting leaves and appeared to be responsible in conjunction with some other rather unfavorable conditions for the young trees. This will probably give more trouble in the culture of the catalpa than the leaf-spot or mildew which

have been known much longer and prove less serious. Early applications of Bordeaux mixture repeated at moderate intervals should check the disease.

Leaf-Spot. The leaf-spot (*Phyllosticta Catalpae* E. & M.) is quite frequent upon the leaves of catalpa. It rarely causes more than occasional spots in the leaves, the injury being in no way comparable to that caused by the catalpa midge. Fungicides should be effective against the true leaf-spot.

Mildew. The leaves of catalpa are often covered over by the powdery mildew fungi (*Microsphaera elevata* Burr., *Phyllactinia suffulta* Reb.). These mildews tend to become conspicuous by the white covering upon the leaves in later summer. While unsightly the injuries are rarely serious.



Fig. 37. Cedar apples caused by rust fungus. In May these dry looking apples send out jelly-like branches filled with spores of the rust fungus. These spores may attack leaves and fruit of apple, as well as crataegus and junberry. (From a photograph by W. P. Beeching).

Root-Rot. Since the recent demand for seedling trees of *Catalpa speciosa*, some difficulties have been met with in diseased seedlings of catalpa. These seedlings are liable to be attacked in their early stages by the ordinary damping off fungi such as *Rhizoctonia*, *Pythium* and *Botrytis*. One interesting case of a true root-rot fungus was studied in 1908. The seedlings were being grown in land that has been used some years for truck gardening; the stand was cut down very much and in later summer some of the seedlings, then a foot or more in height, showed sudden dying and dropping of the leaves; this was found to be due to the root-rot fungus of the violet and tobacco (*Thielavia basicola* Zopf.). This must have been quite serious on the smaller seedlings. At the date of study, September, only the smaller root branches were destroyed by it and the larger ones seemed normal. The injury to these seedlings in dry weather was enough to bring about leaf collapse due to reduced water supply. If this fungus becomes very general it will involve soil treatment for such seed beds. It was too soon to determine how serious it may be upon trees of larger nursery size, although it is not greatly feared.

CELERY

Black-Root, so-called, may be found on celery plants from seed beds. In one instance such plants yielded growths which shortly run to seed and were valueless.



Fig. 38. Celery leaf attacked by leaf-spot. Various troubles produce similar spotting in celery leaves.

Leaf-Spot or Leaf Blight (*Cercospora Apii* Fres.) is a prevalent condition upon celery plants. This is at times attributed to the fungus above named, or others, and is also produced by other causes, as by excess of water during overflow and the like. During certain seasons the loss from the leaf-spot or leaf-blight troubles is very much greater than during others. This is clearly explained when the conditions giving rise to the leaf troubles are apparent.

But this is by no means a common fact, and in some years there is much blighting after the celery has been boarded up for blanching. Usually the fungus is discoverable in diseased areas of the leaves. The use of fungicides, such as Bordeaux mixture, is likely to prove beneficial, especially to protect the plants in the seed bed until transplanted. (See Spray Calendar). While beneficial for later applications in the field, so long as it is not clear that the fungus parasite is not the only cause of blighting or leaf spotting, all possible conditions should receive attention. Kinney (Rhode Island Exp. Sta. B. 44) has suggested that the breaking down of the celery leaves arises from the methods of culture practiced, particularly the level culture, in which the water relations of the plant are not in a natural state. He succeeded in preventing the blighting of celery by mulching with celery tops in which there was a large supply of the fungus. Mulching, especially during periods of prolonged drought, may thus prove profitable. The identification of the particular fungus occurring in the spots must, in each case, be made by the microscope. Aside from the mulching suggested the remedies are stated in Bulletin 121.

The conditions of celery culture are yearly becoming more troublesome and are really serious.



Fig. 39. Younger celery plants attacked by root-rot. These plants are kept alive by new roots, though they increase but little in size. After VanHook, Cir. No. 72.

Heart-Rot is a very destructive decay of the inner, or heart, portions of the celery plant after blanching has begun. The inner parts rot very suddenly, emit a penetrating odor and the market value of the affected celery is destroyed.

The decayed parts are teeming with motile bacteria to which this form of decay has been attributed. The heart-rot prevails too in very hot, steamy weather, but preventive measures are about all that can be recommended. It is suggested that when the boards are first put up to the celery, under such conditions as accompany the heart-rot, they should be left apart at the top and only closed up to the usual point after an interval of several days. This secures better ventilation and often prevents the disease.

Root-Rot. During a succession of wet seasons much trouble developed in the Akron district from attacks of root-rot (*Rhizoctonia*). This gave trouble at times with the seedling plants, but more seriously with the shortened development of the crop. Often the roots were nearly all rotted off. The trouble seemed to decline rapidly with drier seasons. (See Circular No. 72, Ohio Exp. Sta.).

Rust, true and false. In Europe the celery plant is attacked by one or two rust fungi (*Puccinia bullata* (Pers.) and *P. Castagnei* Thüm.) of the same class of parasitic fungi as those producing rust in wheat. These two rusts have not as yet been discovered in America, though they will doubtless in time become introduced. Celery which is banked in the earth often has the blanched stems marked by rusty spots of various sizes. These spots appear to arise from the contact of the stems with the earth, and on microscopic examination seem to be due to the fungi or bacteria, or both, that may be present in the soil. The difficulty is prevented by avoiding this method of blanching and substituting boards or close culture planting.

Bad Seed. There is scarcely a more vital question in celery growing than that of the quality of seed used. Seed that is of a bad strain though true to varietal name, may inflict losses of hundreds or thousands of dollars on large growers. Hollow celery, or that otherwise useless, according to present knowledge is very often due to the bad seed.

CHERRY

Black-Knot. This is a conspicuous disease attacking the branches of cherry and plum trees but is more frequent upon the cherry varieties of the Morello type. It is due to a parasitic fungus (*Plowrightia morbosa* Schw.). Insects, however, make harbors of the interior of the knots. The spores of the black-knot fungus are ripened during the winter and scattered in early spring, finding lodgement on the new branches or in fractures on old ones, where their growth causes the formation of a new knot. Black-knot may be prevented by spraying with Bordeaux mixture, but is more profitably controlled by carefully cutting off affected parts and burning them, making a clean sweep at least once each year and that *previous to March 1st*. This is a practicable measure and we have confidence in its efficiency.

Leaf-Spot and Mildew. The first named disease is caused by the same fungus (*Cylindrosporium Padi* Karst.) as that which we call "shot-hole fungus" on the plum, and may be successfully prevented by the use of Bordeaux mixture, except that only half the strength of mixture may be applied with safety to the foliage of the cherry. (See Calendar). The mildew is usually found chiefly upon sprouts



Fig. 40. Twig of cherry attacked by black knot. This is the summer condition when the conidia are numerous upon the surface and often give an olive color to the knot.

and young shoots. The mildew fungus (*Podosphaera Oxyacanthae* (DC.) De By.) is a very interesting one. This applies especially to amateur microscopic study. If spraying is required for the mildew two applications will probably be very satisfactory.



Fig. 41. Leaf of cherry attacked by leaf-spot fungus. The dead areas in cherry leaves turn dry and rarely give shot-hole effects. The same fungus occurs upon the plum. From Bulletin 79.

Cherry-Rot or Brown-Rot (*Schlerotinia* (*Monilia*) *fructigena* (Pers.) Schw.) affects all stone fruits, including peach, plum, apricot, etc.

It is by far the most serious and baffling of cherry diseases to the commercial cherry grower. The decay of the fruit is caused by the fungus named. The conditions of the season may favor or retard the spread and development of the fungus. The threads of the fungus (mycelium) survive in the rotted fruits, which may hang

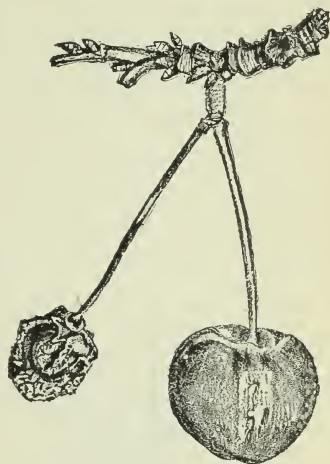


Fig. 42. Cherries, sound and rotted. The parasite in this case is the same as on other stone fruits.

on the trees unless removed. Careful removal of all rotted fruit and spraying for the fungus, as per the calendar, may be relied upon to save a part of the fruit, but judgement and attention to the details of the work are always required. It is to be understood, also, that checking the curculio is a sure means of helping to check rot.

CHESS

Anthracnose. The anthracnose fungus (*Colletotrichum cereale* Manns.) attacks the chess as well as the cereals in which it may grow. The disease is of interest upon chess because it may be a source of extending the development of anthracnose. (See Anthracnose of oats, rye and wheat).

CHESTNUT

Anthracnose is a disfiguring spotting of chestnut leaves, about which inquiries are often made. Small, dead areas with characteristic borders are produced by this fungus (*Marsonia ochroleuca* B. & C.). Such applications of fungicides as are made for shot-hole fungus of the plum and leaf-spot of the horse chestnut, will be found useful when treatment becomes necessary on the chestnut.

Bark Disease. A serious bark disease of chestnut in the east has recently been described and has proved injurious. The fungus (*Diaporthe parasitica* Murr.) appears to enter as a wound parasite through openings in the bark. It has exterminated a part of the chestnut trees in the eastern half of Long Island and about New York City. (See Yearbook, U. S. D. A., 1907, pages 489-490, also Bulletin, Bureau of Plant Industry, No. 121, 1908). The beginnings of the

disease show on branches with smooth bark, by the presence of dead, discolored or sunken patches sometimes covered with the yellow orange or brown pustules of the fungus.

CHRYSANTHEMUM

Leaf-Spot is frequently a disfiguring disease of this plant in earlier growth. It is caused by the leaf-spot fungus (*Septoria Chrysanthemi* Cav.). Two other fungi, a *Phyllosticta* and a *Cylindrosporium*, also attack the chrysanthemum. For indoor treatment copper sulfate solution of one fourth of the strength given in the spray calendar—that is one pound to 50 gallons of water—will prove available. More applications will be required, but the foliage will not be rendered so unsightly as with Bordeaux mixture which, however, may be applied in full strength.

Powdery Mildew. Powdery mildew also occurs upon chrysanthemum foliage. The fungus (*Erysiphe Cichoracearum* DC.) is usually not persistent, but calls for spraying foliage with fungicides when serious.

Ray Blight. A blight of the rays of chrysanthemum flowers due to a specific fungus (*Ascochyta chrysanthemi* Cav.) is reported from the south and is very

liable to be present in Ohio.

Rust. This is found on the chrysanthemum, resembling other rusts in its development. Rusted leaves and badly rusted plants should be destroyed.

CLOVER

Anthracnose. Three anthracnoses occur upon clover; the more common of which is due to the same fungus (*Colletotrichum trifolii* B. & E.) as the anthracnose of alfalfa. In 1907 it attacked the clover over the southern one-third to one-half of Ohio, causing dying of the plants attacked. These show lesions of the stems and leaf stalks and may be detected in the new seedlings in late summer through the dying of the leaves of these plants. It is not known how



Fig. 43. This shows clover plants from fields at the Station attacked by new anthracnose fungus in 1909. This causes the leaves to droop and die; also at times the tips of the stems. From a photograph by T. F. Manns.

serious this may prove upon clover, nor is this one known in northern Ohio.

The second anthracnose fungus (*Glocosporium trifolii* Peck.) has been known longer than the first and occasionally shows by killing the tops of large

clover stems in meadows. It is apparently not a serious disease, although a very interesting one to study in connection with the anthracnoses due to *Colletotrichum*.

The third anthracnose upon clover (*Colletotrichum cereale* Manns.) is the anthracnose of wheat, rye and oats. It was found to a limited extent attacking clover upon the Station grounds in 1909. Except in microscopic characters this anthracnose cannot be distinguished from that of Bain and Essary first mentioned above. In the microscopic characters the two are clearly distinguishable. It is quite probable that this fungus will be found over much of the state.

Black-Spot is due to a fungus (*Phyllachora trifolii* (Pers.) Fckl.) which attacks the leaves of clover causing dead spots and dark discolorations on the under side of the leaves. As a rule these attacks come so late in the working life of the leaves that the injury is slight.

Dodders occur upon clover as well as upon the alfalfa; with it, likewise, there are two species (*Cuscuta Epithymum* Murr. and *Cuscuta arvensis* Beyr.), the seeds of which are distributed in the clover seed. In 1907-8 when the domestic supply of seed ran so low the lack was made good by importations from Europe. This has brought a large amount of dodder into the state, the most of it being the clover dodder proper. With clover seedlings as with alfalfa where infestations are slight it will pay to dig up by root the infested plants and burn them for destruction of possible seeds. Dodder is a parasitic twining plant and may be easily recognized by its appearance. The seeds are illustrated in Bulletin 175.

In the handling of the new clover seedlings infested with dodder, it is probably best to clip in fall to prevent ripening of the dodder seeds. The hay crop may be cut the following season without fear since the seeds will not be in condition to grow. Following the mowing of the hay crop it is probably desirable to break the clover sod after the growth is fairly well started, and before time enough has elapsed to permit ripening of the dodder seeds. In no case is it desirable to cut seed from such dodder infested fields. Dodder in clover hay is held responsible for scouring of cows and horses.

Leaf-Spot. A leaf-spot of white clover referable to an anthracnose fungus (*Ascochyta* sp.) has been described from our region although not definitely determined in Ohio. The injury which may result cannot be now stated.

Rust. The various sorts of the cultivated clover, Red, Alsike, Mammoth, etc., are attacked by a clover rust (*Uromyces Trifolii* (A. & S.) Wirt). If one will examine the small, dark spots in the clover leaves he will find a cluster of this reddish fungus beneath. This rust does not spread to other plants than clovers and is commonly regarded as more disfiguring than destructive. It is not nearly so injurious as the leaf-spot of alfalfa which is similar in appearance.

Root Nodules and Root Tubercles upon Leguminosae. Upon removal of the roots of the clover plant from the soil one finds minute enlargements which are the subject of frequent inquiry. These are nodules or tubercles as they were formerly called, caused by the messmate-living of certain nitrifying organisms, or microbes, with the clover plant. To these microbes in this communal life is due the power of withdrawing nitrogen from the atmosphere and fixing it in the tissues of the clover plants. The same applies in general to the nodules upon plants of this order, the *Papilionaceae*. It thus follows that these nodules are the normal condition of properly nourished leguminous plants of the order *Papilionaceae*, and it likewise follows that the full value of this work of nitrogen fixing is only realized for manurial purposes when the tissues of the clover plants decay in the soil.

Stem Blight of clover has recently been studied at the Station and has been found to be due to the same fungus as that of wheat scab (*Fusarium roseum* Lk.). This fungus has been found to cause the death of seedling wheat plants and to follow harvest by attacks on clover stems. (See Bulletin 203). It appears at this time to be one of the serious forms of clover sickness. The writer looks

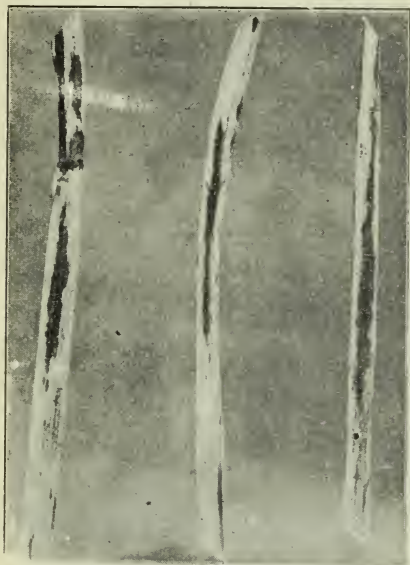


Fig. 44. Red clover stems suffering from stem sickness. The grayish spores in the lesions are those of the fungus of wheat scab. From Bulletin 203.

upon it as liable to be much more serious even than anthracnose. The only present suggestion for control will apply to control of the wheat scab fungus through recleaning of seed and separation of all scab infected kernels. It is quite likely that clover seedlings made in a dry year with little grain scab will not be exposed to the same danger from this blight as those made in wet seasons when the disease is very bad in the grain. (See wheat scab).

CORN

Bacterial Disease. This has been described and illustrated in Bulletin 6 of the Illinois Experiment Station, 1889. The malady infests both younger and older plants. In the younger it causes a yellowish coloring and a general appearance of debility, with death of the leaves, commonly from the point backward.

After midsummer, spots appear on the exterior of the sheaths which are more conspicuous on the inner side and at times more or less smeared with a gelatinous substance. No successful remedy has as yet been proposed.

Dry-Rot or Mold. The dry-rot or mold of corn (*Diplodia zeae* (Schw.) Lev.) was investigated by this Station in 1906, it being reported by a grower in Licking Co. He stated that he had been studying the development for two years; the first time noted, the mold area was small involving but part of one shock; the next year a larger area had been invaded and the year of 1906 he reported his losses were still greater. He reported that conditions clearly indicate the invasion of the soil by the parasite and possible infection through the growing plant. As in this case from Licking county and many others in which continuous corn growing is practiced on rather moist soil, there is great danger from accumulation or infection. The ears attacked were marked by adherence of the husk and the uniform moldy covering matted the kernels together upon the ear and destroyed the feeding value.

In the matter of prevention little can be done beyond avoiding continuous cropping of corn for invaded areas. For life history of the fungus see Circular 117, Illinois Experiment Station; 22nd Annual Report, Nebraska Experiment Station, 1908.

The Leaf Blight Fungus (*Helminthosporium graminum* Rab.) has been noted on corn and has recently been sent to this Station from Vinton county, in the latter case upon sweet corn. The fungus causes somewhat extended, or elliptical

brown (dead) areas in the leaf blades, readily identified by the microscope. All diseases of the young corn attract notice, but it is not certain that there is need to apply fungicides for this fungus, though such might prove successful.

Corn Rust (*Puccinia Maydis* Berang.) is met with in greater or less abundance upon corn every season, the greater abundance usually being in rainy seasons. The rust causes small oblong or elliptical spots on the surfaces of leaf and sheath and in the spots are contained reddish-brown spores of the rust. The shade of the spores will vary with the time and development of the fungus. Here, as with wheat, the fungus passes through the uredo and teleuto stages.

Silage Mold. At times we have complaint of mold in silos where corn silage is stored. Doubtless there is some loss in nearly all cases from different molds



Fig. 45. Stem of maize attacked by smut. The smut boils shown here later burst open and scatter masses of smut spores.

or decays where the air circulates in contact with silage. We have investigated the mold fungus (*Penicillium* sp.). This is possibly the same blue mold which we have found to attack fruits in storage and transit. It is not an active organism and must be held in check by control of conditions in the silo.

Corn Smut is a well known disease, attacking leaves, shoots, ears, tassels and brace-roots of corn, converting the diseased parts into masses of dirty (smutty) spores of the fungus (*Ustilago Zeae* (Beckm.) Unger). A brief article upon corn smut will be found in Bulletin 78. (See also Bulletin 92 of the Kansas Experiment Station). The corn smut may be propagated by smutty seed, although much more likely to be carried by the transportation of the yeast spores of this smut fungus which may light upon any young growing part and produce smut infection. From this fact and from another—probably a greater



Fig. 46. An ear of corn partly destroyed by smut. Other ears may be found showing different forms of attack.

prevalence of the smut yeast spores in later summer—later growing parts, for example, tassels, brace-roots, ears and sucker shoots, are perhaps more often attacked by the smut. The smut spores may be scattered in manure if smutted fodder is used, and it seems well proved that manured land yields more smutted corn than unmanured. The same may be true of clover sod as compared with corn stubble. The reason would exist in the decayed vegetable matter, wherein the secondary yeast spores of the smut may grow and then may be carried to the corn which becomes thus affected. Treatment of seed corn does not apparently reduce the amount of smut. Cutting and burning the smut boils before they have burst open would be useful. It is worth while to fight smut by all available means.

COWPEA

Leaf-Spot. In southern Ohio where these are grown there is danger of the leaf-spot (*Cercospora*). This is not liable to be very serious.

Wilt. The wilt fungus (*Necosmospora vasinfecta tracheiphila* Erw. Sm.) is more serious, although at present largely confined to the southern districts. For Ohio conditions the practice of growing cowpeas is not of such extent as to threaten seriously with this disease.

CRABAPPLE

Scab. The same scab which attacks the common cultivated sorts also attacks the crabapple, including both fruit and foliage. The remedy is that given under apple.

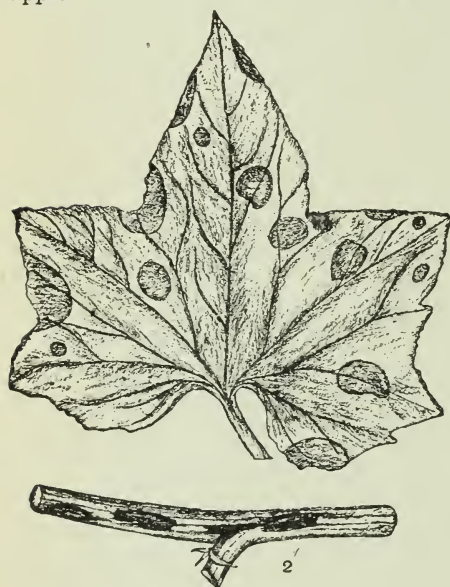


Fig. 47. Cucumber leaf and stem attacked by Anthracnose. The dead areas in the cucumber leaf, caused by Anthracnose, are usually larger and more nearly circular in outline than with downy mildew.

Rust. The same rust fungus (*Gymnosporangium macropus* Lk.), in the cluster cup stage appears on the crabapple leaves and fruit as well as upon the leaves and fruit of apple, and leaves of crataegus. (See Apple).

CROCUS

Root-Rot. Little study has been made with us of the diseases of bulbous plants, yet we are liable to import those occurring in Europe. The common root infesting fungus, *Rhizoctonia*, is one of the determined troubles of crocus in France. Microscopic identification of the trouble should be easy owing to the characters of the fungus.

CUCUMBER

Anthrachnose (*Colletotrichum* *Lagenarium* (Pass.) Hals.). This fungous disease attacks nearly or quite all cucurbits as well as the bean. Upon the cucumber in Ohio

it is apparently more destructive during the earlier season. The fungus may be found in the greenhouses at all cultural periods, as well as in the field. It causes circular dead spots in the leaves, usually more than one-fourth inch in diameter, and likewise elongated brown areas on the stem. (See Bulletin 73, 89 and 105)

Unlike the downy mildew, anthracnose may be checked after it appears, though best prevented by earlier applications of the fungicide. In the field, Bordeaux mixture is to be preferred; in the greenhouse, copper sulfate solution, one pound to 50 gallons, has proved efficient and has checked the anthracnose after one-fourth of the plants had been destroyed by it.

Damping-off is a frequent trouble upon greenhouse cucumbers. It is serious often where plantings are made following lettuce attacked by rosette. The fungus in that case is the same as lettuce rosette (*Rhizoctonia*) or lettuce drop (*Botrytis*). There is a strictly damping-off fungus (*Pythium De Baryanum* Hesse) that is sometimes troublesome. The *Botrytis* named at times attacks pruned parts of cucumber plants, also extending its attacks to the blossom end of young fruits.

The results of *Rhizoctonia* on greenhouse cucumbers have been curious owing to attacks on the smaller root branches or rootlets. The growth of the vines is at times checked, accompanied by coloring of the leaves and reduced fruitfulness. Some growers have given the name "leaf-curl" to this phenomenon but it is strictly the effect of the fungus named. It has been found necessary in soil treatments where cucumbers follow affected lettuce to increase the strength of formalin drench to 4 or 5 pounds per 50 gallons of water. (See Soil Diseases).

Downy Mildew. Downy mildew fungus (*Plasmopara Cubensis* (B. & C.) Humph.) is late in its attacks, not having been found in Ohio fields earlier than August 3rd. It causes angular, yellowish spots on the leaves, followed by yellowing of the whole leaf and death, as by frost. It spreads with extraordinary rapidity, requiring only three or four days to become disseminated throughout a large field. Unlike anthracnose, it may not be successfully checked after its appearance, and it is not safe to leave untreated plots in fields to be sprayed. July 25th to August 1st is sufficiently early to begin spraying for mildew, but applications should be repeated at intervals of 7 or 9 days. In 1898 an increase of 75 bushels per acre, of sprayed over unsprayed cucumbers, was obtained at Creston. (Bulletin 105). Cucumber pickle growing finds in this mildew its most serious enemy. If any of the crop is to be harvested after August 20-25 spraying with fungicides appears necessary. Early planting may permit gathering the crop before this date. The downy mildew is also very destructive in the forcinghouse, and is to be treated with the same fungicides recommended for anthracnose. (Bulletins 73, 89 and 105).



Fig. 48. Cucumber leaf from greenhouse, attacked by Downy Mildew. The spots in the leaves caused by the mildew are usually outlined by the veinlets of the leaf.—From a photograph by T. F. Manns.

Leaf-spot of cucumber is also due to fungi. (*Phyllosticta Cucurbitacearum* Sacc. and *Cercospora Cucurbitae* E.&E.) Of the two species named, the *Phyllosticta* was the commoner in thrifty pickle fields in 1898; the *Cercospora* being apparently confined to wet fields, though this cannot be expected to hold true under all circumstances. The *Phyllosticta* was found almost exclusively upon the unsprayed pickle plants and seems, therefore, amenable to the same treatment as applied for downy mildew. (Bulletin 105).

Mosaic Disease of greenhouse cucumbers has been recently studied in Ohio. This disease is analogous in character to the mosaic disease of tobacco and tomatoes and to the yellows of the peach. It is due to an oxidizing ferment in the leaves and is transmitted like the tobacco mosaic disease, by touching first diseased and then healthy plants. The fruitfulness of these variegated yellow plants is very low and it is best at all times upon the appearance of the disease to remove the diseased plants and destroy them.

Nematodes or Eelworms (*Heterodera radiculicola* (Greef.) Mull.). These minute parasitic worms are often very destructive upon cucumbers under glass.

They are especially so in some cases recorded in Bulletin 73. The greatest injury may occur on the seedling plants, but plants of all ages are destroyed by the parasitic worms. Their presence may be known by the small, bead-like enlargements produced upon the roots or rootlets. This matter is treated at some length in that Bulletin. No remedy has been discovered that is effective with plants once attacked by eelworms. The time to prevent this trouble is in the selection or preparation or treatment of the soil for greenhouse benches. Indeed the nematodes seem to be present in old sod, and to some extent in decaying vegetable matter generally. An effective remedy against eelworms consists in steaming and so treating the soil that the parasites will be destroyed. For this procedure see calendar and Bulletin 73. Also Massachusetts Exp. Sta. Bul. 55, In thus handling the soil due time must be given for draining and drying.



Fig. 49. Roots of seedling cucumber with Nematode galls upon them. These cause collapse of the plants.

Powdery Mildew (*Erysiphe Cichoracearum* DC.) of cucumbers is also frequent in the forcing house, but rarely destructive elsewhere. For this fungus a dilute copper sulfate solution is effective. See Bulletin 73.

Root-Rot. The root-rot or so-called "leaf-curl" development on matured cucumber plants referred to *Rhizoctonia*, is often serious. It is more fully discussed under damping-off above.

Spot of Cucumber Fruit or Cucumber Scab (*Cladosporium cucumerium* Ell. & Arth.), has been reported upon cucumbers by Dr. Arthur (Ind. Exp. Sta. Bul. 19), and may prove injurious if prevalent. It should be found amenable to the same treatment recommended for anthracnose and downy mildew.

Cucumber Wilts. The wilt diseases of cucumbers, likewise of other cucurbits, are a source of usual complaint in the earlier season, as the plants are beginning to form vines. In 1899 these complaints continued much later. The plants suddenly wilt down as from lack of water, then soon die. What has been referred to the same general cause was also observed in the cucumber forcing-house, apparently starting in the leaves. Smith (Proc. Am. Ass. Adv. Sci. 1893) refers this disease to a bacterium (*Bacillus tracheiphilus* Smith) which is transferred from diseased to healthy plants by the cucumber beetle and the squash bug. This form of wilt has been found on cucumbers, muskmelons and squashes

in Ohio. In addition we have found to a limited extent, another wilt disease of the cucumber which appears to be similar to that described by Dr. Smith. (Proc. Am. Ass. Adv. Sci. 1895, p. 190). On watermelons in the South he finds a trouble with which ours may be identical. (Bul. 105, p. 222). This latter is referable to a species of fungus, a fusarium (*Fusarium niveum* Smith), which grows internally in the stem and finally plugs up the water vessels in a manner similar to the work of the bacterial wilt. Spraying is unlikely to be beneficial for this wilt or for the bacterial one. Preventive measures suggest gathering and burning infected vines, and especially waging a successful war against the insects; these should prove more or less successful according to thoroughness of work. The fusarium wilt calls for rotation of crops. Much may be finally done by breeding varieties resistant to wilt.

CURRENT

Anthracnose. The anthracnose (*Gloeosporium ribis* (Lib.) Mont.) of the currant has occurred occasionally and will apparently be checked by the same treatment as given for raspberry anthracnose.

Cane Blight is a very serious disease whenever stools are attacked by it. The fungus (*Nectria cinnabarina* (Tode) Fr.) survives by its threads in the tissues of the stool and upon the death of the canes develops as a bright pink mass of the fungus upon dead parts. While spraying may, and surely must, keep down the risk of infection, whenever stools show attacks by dying of a part of the canes and the development of this fungus these infected stools are doomed and should be removed and burned.

Black-Knot. A black knot fungus (*Plowrightia ribesia* Pers.) has been described upon currant, and is always a possibility with us. It attacks the branches or stems.

Dropsy. This disease has been met with. It causes very considerable enlargement upon the young stems of the currants, not unlike in appearance the enlargements due to crown gall in the peach, except that usually more of the stem is involved than in the other case. The trouble appears to be due to physiological causes and the pruning knife may aid cultural efforts.

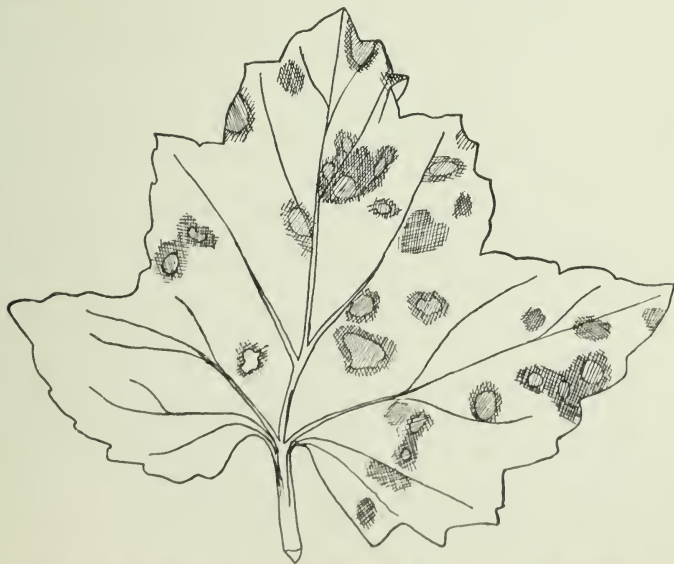


Fig. 50. Leaf of currant attacked by leaf-spot. The dead areas are easily seen in the currant leaf but the fungus is difficult to discover.

Knot. This fungus (*Pleonectria berolinensis*, Sacc.) is a stem trouble of currants and calls for investigation. It has been collected in this state.

Leaf-Spot of currants is referable to two species of fungi (*Septoria ribis* Desm.; *Cercospora angulata* Wint.) of which only the *Septoria* has been discovered in Ohio. (See Bulletin 79). These fungi produce early spotting and premature dropping of the currant foliage; in some instances the leaves drop even before the fruit has ripened. Bordeaux mixture applied as per calendar is effective against this disease, though late applications may render it necessary to wash the fruit. For this reason, if for no other, the first application should be made very early and followed by about two more at fortnightly intervals.

Rust. A rather common rust fungus (*Puccinia ribis* DC) has been discovered upon currant. Warning has been recently sent out against a second fungus (*Cronartium ribicolum* Dietr. *Peridermium strobis* Kleb.) which attacks the seedlings of white pine in the aecidial stage, and passes its uredo and teleuto stages upon leaves of currants and gooseberries. This fungus is to be sought for with care since its occurrence in the United States may have much to do with the success of forest plantings of white pine.

Powdery Mildew of gooseberries (*Sphaerotheca mors-uvae* (Schw.) B.&C.) sometimes attacks currants where it is apparently less destructive than on gooseberry. Reasonable spray treatments should control it.

DEWBERRY

Leaf-Spot. (*Septoria rubi* West.) Cultivated dewberries as well as the wild sorts, are peculiarly susceptible to the attacks of the leaf-spot fungus. It causes very small grayish spots in the leaves. The same fungus attacks blackberries and raspberries, as previously stated. It may be prevented by a careful application of Bordeaux mixture.

Rust. The bramble rust also attacks the dewberry as in the case of blackberry. For treatment see blackberry.

EGG-PLANT

Anthraxnose. The anthraxnose fungus of egg-plant (*Gloeosporium melongenae* Ell. & Hals.) attacks the fruits of egg-plant and causes spots in them. This occurs frequently in Ohio. These show early as pits in the surfaces of the fruit which show the usual border.

Bacterial Blight. The common solanaceous blight organism (*Bacterium solanacearum* Erw. Sm.) attacks the egg-plant as well as the potato and tomato. Where attacks occur destruction of the affected plants is all that can be done.

Fruit-Rot. A fruit-rot of egg-plant likewise occurs and may at times appear as a leaf-spot fungus. This, like the anthraxnose and leaf-spot, should yield to treatment by sprays. Ammoniacal copper carbonate may be used toward the ripening period.

Leaf-Spots. Two or more leaf-spot fungi have been recorded on egg-plant and will doubtless be found when sought.

Stem-Rot. The stem-rot fungus of sweet potato (*Nectria ipomoeae* Hals.) has been described upon egg-plant by Dr. Halsted. The conidial stage is evidently a species of fusarium and it may or may not be a different one from that with which we have to contend upon the potato; it is recorded by Dr. Halsted as the same that occurs on sweet potato.

ELM

Bleeding. Bleeding of pruned elm trees is often annoying as well as dangerous. Mr. Boddy, City Forester of Cleveland, thinks asphaltum covering over cut surface reduces or cures the bleeding. This is successful when searing by torch precedes application of dressing.

Black-Spot. The leaves of ornamental elms are attacked by black spots (*Dothidella ulmi* (Duv.) Wint.) (*Gnomonia Ulmea* (Sacc.) Thuem.) which sometimes injure the leaves, and by this means checks the tree.

Other Leaf Diseases also occur upon the elm. One of these is a leaf-spot (*Phyllosticta ulmicola* Sacc.) which matures its spores in the fallen leaves. Gathering and burning these infested leaves will prove a check on this fungus.

The **Powdery Mildews** (*Microsphaera Alni* D.C. and *Uncinula macrospora* Pk., more often the latter) likewise attack elm leaves. If troublesome these should be reached by applications of Bordeaux mixture, making the first application when the leaves are half grown.

Timber-rots are also known on the elm; to be guarded against in wound infection of shade trees.

Twig Disease. In portions of Ohio and in Kentucky a dying of elms which are prized as shade trees has been reported. This disease shows first as a loss of leaves at the ends of twigs, often at the tops of trees. (See Kentucky Exp. Sta. Bul. 84). It is believed by Prof. Garman that changing soil conditions have much to do with this disease. To the writer it would seem that the water factor with this, as with many other shade trees, may prove a determining cause. At any rate, the time has come for a study of these water problems in shade trees.

EMMER

Anthracnose, Scab, etc. Emmer and its near relative, spelt are attacked in Ohio by the Anthracnose (*Colletotrichum cereale* Manns) and by the scab (*Fusarium roseum* Lk.) These diseases are the same as those occurring upon rye, wheat and other cereals under which heads fuller notes will be given. (Also see bulletin 203).

FIG

Leaf Diseases. The fig is frequently grown in conservatories and is often attacked by leaf diseases. The commonest leaf fungus (*Cercospora Bolleana* (Thuem.) Speg.) of the Mediterranean region is a serious leaf disease. The attacked spots assume a brown color, the leaves eventually yellowing and dropping off. Where leaves of fig begin to drop from such causes, a spraying with Bordeaux mixture should be applied upon the younger leaves.

FILBERT

Black-Knot (*Cryptosporella anomala* (Pk.) Sacc.) has been found upon cultivated filbert or hazel-nut in New Jersey and Massachusetts (N. J. Exp. Sta. Rept. 1892 and Mass. Exp. Sta. Rept. 1892). This is a serious stem disease which may check successful culture when it occurs.

FLAX

Dodder. Flax is attacked at times by a seedling parasite, flax-dodder (*Cuscuta Epilinum* Weihe) whose tiny, leafless stems wind about the flax plant and by haustoria, or sucking organs penetrating the epidermis, draw from it substances essential to healthy growth. The dodder seeds are carried in the flax seed and prevention must seek to avoid the seeds.

^a **Other Diseases** of flax are noted to occur in the Northwest among which are a *Fusarium* wilt and a *Colletotrichum* blight. (See bulletins 50, 55 and 71, North Dakota Exp. Sta.).

FOREST SEEDLINGS

Forest seedlings as will be noted under Catalpa, Pine and Spruce are especially liable to certain disease attacks upon the young plants. The number and variety of these diseases is scarcely realized until one begins to care for their survival as in forest culture. It will usually be found in newly cleared areas used for this purpose that the leaf mold is badly infected with seedling parasites. Some treatment of this soil before using as seed beds is desirable. For some of the commoner damping-off fungi the formalin drench may succeed. For coniferous seedlings, other treatments may be required. Recently the United States Department of Agriculture has reported upon two methods of treatment which consist of the use of dilute sulphuric acid, or mixtures of lime with powdered copper sulfate. (See circular No. 4, Bureau of Plant Industry, United States Department of Agriculture).

GINSENG

Leaf Blight or Leaf-Spot, (*Alternaria* sp.) occurs upon ginseng plantations. These have been checked at times by spraying with Bordeaux mixture, while at other times the sprays being made immediately before cold weather caused serious losses.

Root-Rot. The root-rot fungus (*Thielavia basicola* Zopf.) has been found in New York by Van Hook to attack the roots of ginseng and cause destructive rotting. This may prove a serious drawback to ginseng growing, and methods of prevention are difficult to propose. (See Cornell Exp. Sta. Bul. 219).

GOLDEN SEAL

Leaf-Blight of golden seal occurs in many plantings. It is due to a fungus of the same genus (*Alternaria*) that proves troublesome on leaves of ginseng. Spray applications need to be worked out for it.

GOOSEBERRY

Leaf-Spot. The gooseberry leaves are attacked by the same leaf-spot fungus recorded upon the currant (*Septoria ribis* Desm.), although the defoliation may be even more severe than on the currant. In spraying experiments at this Station, conducted by the Horticulturist, it has been found that the gooseberry leaf-spot is more easily prevented than the currant leaf-spot. Indeed no fungus disease upon which we have experimented is more easily prevented when the fungicide is applied at the proper time. (See Spray Calendar). Often the leaves from gooseberry plants have all dropped before maturity of fruit, and in hot weather all the fruit has been lost on the unsprayed, check plants, while the sprayed plants gave a fine yield of satisfactory fruit.

Powdery Mildew (*Sphaerotheca mors-uvae* (Schw.) B. & C.) is a destructive fungus disease especially common upon English varieties, such as Industry, Crown Bob, &c. It has been destructive also upon the Houghton. As already stated this mildew attacks currants. From the nature of this fungus the first spraying with Bordeaux mixture should be made early in the season. (See Bulletin 79). Subsequent applications may be either of Bordeaux mixture or potassium sulfid. (See Calendar). After fruit is half grown the latter fungicide is to be preferred since it is more easily removed from the fruit.

Rust. See currant rust.

GOURD

Anthraxnose, Downy Mildew, &c. Gourds are susceptible to the same fungus diseases as the cucumber. The two most conspicuous are anthracnose and downy mildew. The anthracnose, especially, causes spotting and discoloration on the gourds. This may be arrested if, when the gourds are gathered, they are subjected to treatment with scalding water; otherwise the development of the fungus continues while the disfiguring increases. Field treatment in this case is the same as recommended for like diseases of the cucumber.

GRAPE

Anthraxnose. As is well known we have a long list of fungi attacking the grape, among them the anthracnose fungus (*Sphaceloma ampelinum*) which is found upon leaves and stems as well as the fruit, causing definite sunken spots, usually with a central area of lighter color. Upon the fruit the appearance has suggested the name "bird's-eye-rot" and the last the name bitter-rot. Where prevalent the anthracnose may be entirely prevented by following the directions in the use of Bordeaux mixture as given in the calendar.

Bitter-Rot (*Melanconium fuliginum* (Scrib & Viala) Cav.) of the grape is sometimes prevalent but perhaps less frequent in Ohio than the black-rot.

Black-Rot (*Guignardia Bidwellii* Ell.) is one of the most troublesome and destructive of grape diseases. It chiefly attacks the fruit and causes dark spotting and rotting of the



Fig. 51. Grapes attacked by anthracnose, also called Bird's Eye Rot.

green berries, but it may also attack the leaves, petioles and cluster branches, producing circular or elongated dead spots in them. The rotted fruits persist upon the branches and may hang on over winter, thus carrying the fungus from year to year. This disease, if neglected, is very destructive and the longer the neglect the greater is the difficulty in prevention. Because of the circumstances stated, delay in beginning the treatment increases the difficulty. It is apparently essential that first applications of fungicide for the black rot be made while the vines are dormant and that these be very thorough, followed by the later applications as per calendar. Omission of the spraying just before the blossoms open may lead to ragged clusters, from dropping of the small grapes. (See report of the U. S. Dept. of Agr. 1896). (Ohio Exp. Sta. Bul. 130).

Crown-Gall. Crown gall of the grape is known to give trouble in Ohio. This comes as enlargements near the crown and on the roots. The latter occurring upon raspberry, peach, etc. It is believed to be due to the same cause as the other crown galls and to be handled only through removal



Fig. 52. A cluster of grapes attacked by Black-rot. The rotting grapes are light brown in color immediately following decay.

Downy Mildew (*Plasmopara viticola* (B. & C.) Ber. & D'Ton) of the grape is a prevalent fungus disease which has long been known and repeatedly studied. By it the leaves are attacked and the fungus forms in them oospores by which the winter is passed. The fungus also attacks the berries, causing brown-rot. Gathering and burning the fallen leaves may therefore be useful. No particular difficulty attends the prevention of downy mildew if spraying is thoroughly done.



Fig. 53. Leaf and stem of grape attacked by Black-rot. The lesions in the stem are dark colored. Those in the leaf show as dying areas.

Powdery Mildew (*Uncinula necator* Schw.) is likewise prevalent upon both leaves and fruit. Like all powdery mildews the parts attacked are covered over by the web-like threads of the mildew fungus. This is successfully prevented by the use of Bordeaux mixture as elsewhere directed. (For illustrations of grape diseases see Report U. S. Dept. of Agriculture 1886 and 1887; also Scribner, "Fungus Diseases of the Grape, etc.").

Stem Cankers. Stem cankers of the grape are rather frequent. Many of these are due to injury caused by freezing by which dead spots are produced and in the process of healing these injuries become surrounded by excessive growth and enlargements. In some instances the enlargements obtained a diameter of two or three times the size of the stem. The preventive measures are the same as for any freezing injury, viz., drainage and prevention of excessive late growth.

Dying of grape canes has been studied in one vineyard where it appears also to be associated with crown gall and to result from other diseased conditions. (See circular 64). In this case a portion of the vineyard died out almost completely; followed by sprouting of a portion of the roots. In August there was wilting and drying up associated with diseased stem conditions.



Fig. 54. Illustration showing stroma of a fungus believed to take part in death of grape stalks. The separate dot-growths are at times united into elongated ridges. From Circular No. 64.

The history of this case indicates that the removal and replanting of vines will be more successful than to endeavor to start vines again by sprouts from bases of injured vines.

White-Rot. Diseased conditions of the earlier stages of black-rot showing light color of the berries leads to the use of the term white-rot. As yet, however, the writer has never conclusively proved that we have a white-rot development different from this stage of the black-rot of the grape in Ohio. Where growers suspect this form of rot the method of treatment is the same as for black-rot.

GRASSES

Anthracnoses, Smuts and Rusts are found upon the grasses. These are in part described under blue-grass, orchard-grass, red-top, timothy, and chess.

HAZELNUT

See Filbert.

HEMLOCK

Hemlock grows freely with us and is apparently quite free from foliage troubles.

Heart-Rot (*Trametes pini* (Brot.) Fr.) and **Sap Rot** (*Fomes pinicola* (Sw.) Gill) are reported from districts where special attention is given to the conditions.

HICKORY

Leaf-Spot. A hickory leaf-spot (*Marsonia juglandis* (Lib.) Sacc.) is quite general and leads to dying of the leaves prematurely. This really merits much closer study than has yet been given it in our state.

HOLLYHOCK

Anthracnose (*Colletotrichum malvarum* (Braun & Casp.) Southw.) An illustration has been published in the Journal Mycology (Vol. 6:46-48). It may attack any part of the plant, and is a serious trouble where it occurs.

Leaf Blight (*Cercospora Althaeina* Sacc.) is another fungus disease of the hollyhock. These two diseases of the hollyhock should be amenable to spraying with standard fungicides.

Rust (*Puccinia malvacearum* Mont.) On the other hand this recently introduced disease of the hollyhock is much less likely to be prevented by spraying. The rust fungus forms dense patches, spots or sori, on the under side of the leaves. These are commonly about one-sixteenth inch or more in diameter, of grayish-brown color and projecting below the leaf surface, while a minute yellow spot early appears on the upper surface of the leaf. Subsequently the diseased leaves drop and by the time the plants are blooming the the stem below is bare or disfigured by the remains of the diseased leaves. At the Station this rust has been prevalent and the complaint is general respecting the same trouble. It would seem wise to gather and burn all the affected leaves and likewise the old stems as early as possible. Between anthracnose and rust these popular old flowers are having, at present, a difficult time of it.

HORSE-CHESTNUT

Leaf-Spot of the horse-chestnut (*Phyllosticta paviae* Desm.) is quite frequent. During 1908 and 1909, tip-burn was associated with leaf-spot; as near as could be determined, the tip-burn followed punctures of leaf hoppers or other insects and the plants made very restricted growth during the season. It may be necessary to take combined spraying applications for leaf-spot and the insect troubles. Bordeaux mixture is recommended for this purpose and has in the past given very satisfactory results for leaf-spot. The first application should be made when the leaves are about half grown, to be followed by others at intervals of three weeks.

HORSERADISH

Leaf Blight (*Ramularia armoraceae* Fckl.) is frequent upon horseradish and is also found upon other mustard plants. Ordinarily the severity of attack does not call for spray treatment.

Leaf-Spot (*Cercospora armoraceae* Sacc.) is less frequent and not serious in its effects.

White Mold (*Cystopus candidus* Pers) which is so common upon shepherd's purse and other low plants of the mustard family, likewise attacks horseradish. Owing to the heavy root development of horseradish the temporary parasitic attack does not give noticeable injury.

HYDRANGEA

Leaf Blight. A leaf blight fungus (*Phyllosticta Hydrangeae* E. & E.) has been observed on Hydrangea by Dr. Halsted in New Jersey. This may be serious at times upon this ornamental plant.

Rust. Hydrangea is likewise attacked by the rust fungus. (*Melampsora Hydrangeae* DC.) This may also be at times, quite serious. Remedies for neither of these troubles have as yet been worked out.

IRIS

Bulb-Spot. Massey has reported a fungus causing black patches on the surfaces of iris bulbs. This fungus (*Myrothecium aductum* Mass.) from a description given, resembles onion smudge in its appearance and effects. Loss is prevented by soaking the bulbs for an hour in Formalin solution.

Leaf-Blight. The leaves and roots of iris have been reported in England to be attacked by a fungus. (*Botrytis galanthina* Mass.) This disease is likely to be present in shipments of iris about the world. It is described as first attacking the leaves and later destroying the root, thus causing the death of the plant.

IVY

Leaf-Spot and Leaf-Blight. Leaf diseases of English ivy are occasionally reported but have not been studied for our district. Dr. Halsted has described a blight upon variegated forms of English ivy (*Vermicularia trichella* Hals.). In this connection we need to bear in mind that variegated plants are especially susceptible to disease and are therefore liable to suffer.

JAPAN CREEPER

See Virginia Creeper.

LARCH

Canker and Rots. Larches are but little grown in our territory. In Canada there has been described a larch canker (*Peziza willkomii* Hartig.) This attacks the trunk and branches. In common with other conifers the larch suffers from tree infecting rot fungi. The lack of American data upon these diseases emphasizes our need for such studies.

LEMON

Greenhouse specimens of lemon trees are a source of a good many inquiries. These are chiefly leaf diseases which arise from the brown molds and other fungi infesting these plants. As a rule they are amenable to spray treatments with standard fungicides.

Rots. Allusion has been made to storage and transit rots of citrus fruits. The lemon is no exception to the attacks of these rots. The blue mold (*Penicillium*) is a very common form, and may be met with in almost any of the ordinary shipments of lemons. Brown-rot (*Pythiacystis citrophthora* R. E. Sm.) is a serious trouble in California lemons especially. It appears as a white mold on the surface of affected fruit.

LETTUCE

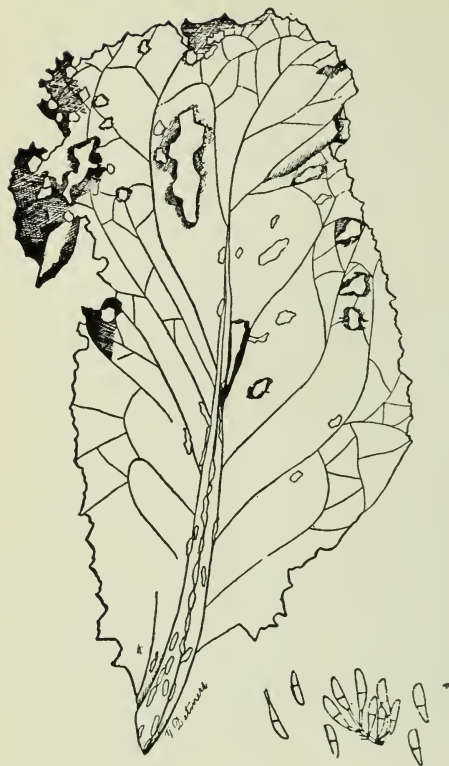


Fig. 55. Lettuce leaf attacked by Anthracnose. The dead spots caused by this fungus frequently break loose and drop out, causing perforation of the leaves. On the midrib the lesions are deep-seated. The two celled spores are shown highly magnified. From Bulletin 73.

Anthracnose or Leaf Perforation. This disease of lettuce was discovered by the writer in 1896 and sent to Dr. J. B. Ellis for description of the fungus (*Marsonia perforans* E. & E.) It shows upon the lettuce plants as dying of spots in the leaves which break free and drop out. The fungus also produces lesions in the midrib of the leaf. In cases of young leaves the attacks of the fungus causes distortion of the leaf, especially toward the top. Apparently very few plants recover after being once attacked, although one may reasonably keep down this disease in the seed beds and young plants by the use of Bordeaux mixture. For houses once seriously infested, thorough fumigation and soil treatment would probably be profitable. It is not generally distributed.

Downy Mildew (*Bremia Lactucae* Regel) is the work of another fungus which belongs to the same class as the downy mildew of the cucumber. It forms yellow spots in the upper leaf surface which appear below as whitened, downy covered areas. Like the downy mildew of cucumbers this one may spread very rapidly under favorable conditions, such as warmth and

surface watering in the greenhouse. Keeping water from the foliage by sub-irrigation of the beds has been found very beneficial (Bulletin 73). Gathering and burning the diseased leaves or plants will usually repay the labor. Particular attention to heat and moisture will usually render spraying unnecessary and it is certainly inadvisable except to eliminate the fungus from the house. Avoid too high temperature or too much moisture on plants.

Rosette or Rhizoctonia. This is a very troublesome disease of greenhouse lettuce which arises from the accumulation of the sterile fungus (*Rhizoctonia* sp.) in heavily manured soils used for continuous greenhouse culture. Upon the young seedlings the Rosette fungus produces stem lesions and rotting off or damping off of the plants (Fig. 57) or with larger plants which are later attacked upon the branch roots or rootlets, the restricted root development prevents growth of the plant axis and gives a basal development of normal leaves with a rosette-shortened center of leaves. Where serious, the crop is shortened very much and

the loss of stand on smaller plants is frequently very heavy. Good results in prevention have been obtained, both from steaming and from formalin drench as per directions in seed and soil treatments. The fungus also attacks the succeeding crops of tomatoes, cucumbers, etc. Attention must in all cases first (be given to growing healthy seedling plants, to be followed by soil disinfection. See Circular No. 57).



Fig. 56. On the left is shown a healthy lettuce plant, on the right diseased lettuce plant with Rosette effects produced by inoculation of pure culture of *Rhizoctonia*. The effect of the Rosette Fungus is shown in destroying absorbent rootlets and in the growth of additional new roots; it also prevents the proper development and elongation of the axis or stem of the plant. From Circular No. 57. (See also Fig. 57).

Lettuce Rot or Lettuce Drop. This is by all odds the most troublesome disease to the lettuce grower. The plants may rot off at the surface of the earth and the central parts, especially of head lettuce, may become attacked by the rot fungus (*Sclerotinia Libertiana* Fekl.) (*Botrytis vulgaris* Fr.). The fungus appears as a whitened covering with a liberal production of spores in clusters. At this Station it has not been possible to succeed with the head lettuce because of the rot. Fumigation of house, the use of fresh or steamed earth each year and the careful regulation of temperature and water supply, seem to be the measures most favorable to prevention. A low night temperature, less than 50 degrees F. is very desirable, while too high a temperature will usually result in disease. Ventilation is all essential during the day. It is desirable also to gather and burn rotted leaves and plants.

Leaf-Spot. The leaf-spot fungus (*Septoria consimilis* E. & M.) is frequent upon wild lettuce plants and occasionally upon outdoor lettuce, especially in late seasons. The small characteristic leaf-spots are not difficult to distinguish from anthracnose. The remedies are confined to avoidance.

Root-Rot and Stem-Rot. A bacterial stem-blight has been described from Vermont, but has not been found with us. A recent stem-rot infection closely resembles rosette in the behavior and form of affected plants. Microscopic

examination shows that the stem tissues are somewhat brown and that the brown and dead rootlets are occupied by the fungus which is referred to a species of *Fusarium*. This disease is at present under investigation and should be controlled, if at all, by the thorough soil treatments recommended under lettuce rosette. It will be no use to disinfect the houses and then grow plants in diseased soil.



Fig. 57. This shows root portions of seedling lettuce plants with dark spots, lesions caused by attacks of the rosette fungus, *Rhizoctonia*. With the younger plants these attacks cause large mortality and in very small seedlings the stem of plantlet may early collapse after the manner shown in rotting specimens. (From Circular No. 57).

Tip-burn. Tip-burn of lettuce leaves is often brought to notice. Usually it is associated with unsatisfactory watering in the greenhouse, or with extreme changes to summer weather. The remedy consists in the methods of watering employed.

LILY

Lily diseases are frequent in all lily growing districts. With us no study has been made, as little complaint is made to us. Doubtless the chief factor is to secure healthy bulbs.

LOCUST

Heart-Rot (*Trametes robiniophila* Murr. and *Fomes rimosus* Berk.). In southern Ohio the locust is reported as suffering from a heart rot trouble, but to which of the several species occurring in different parts of the United States, we must ascribe most injury we are not yet able to decide. Both species occur in Ohio. The rot is described as infecting the heart of much of the trunk, so that trunks may be of no value above the first post length or less from base. The heart wood is converted into punk and the fungus fruits externally, as is commonly the case.

LUPINUS

Several species of lupinus are used for ornamental or other plantings and are liable to the same group of diseases as are found upon alfalfa, clovers and pea.

MANGEL-WURZEL

Mangel-wurzel being a near relative of the beet is liable to be attacked by essentially the same diseases as the garden beet. These are usually leaf-spot, rust, dry-rot, etc.

MAPLE

Anthraxnose. (*Gloeosporium apocryptum* E. & E.) This disease attacks young Norway maples (See N. Y. Sta. Report '95) and has been also identified on the young shoots of sugar maples in Ohio. The new leaves were reported destroyed by the fungus which is much more common in Ohio on sycamore trees. Applications of Bordeaux mixture should check this disease.

Rhytisma and Leaf-spot. The leaves of cultivated maples are often disfigured by dark colored incrustations following the line of the veins. These incrustations are almost black and are caused by a fungus, (*Rhytisma acerinum* (Pers.) Fr.) The trouble is usually not serious, but if prevalent it would seem advisable to gather and burn all leaves attacked by it. The leaf-spot fungus (*Phyllosticta acericola* (Cke. & Ell.) often causes small spots, or dead areas, in the leaves. This may sometimes prove so serious as to call for applications of fungicides.

Mildew. Maple leaves are overrun by the powdery mildew fungus (*Uncinula*) at times, but this is not difficult to check even if spraying becomes necessary.

Tip-Burn—Sun-Scald. Tip-burn conditions upon the maple in 1908 and 1909 were similar to those described for horse chestnut and evidently due to secondary consequences of insect punctures.

Sun-Scald or winter injury effects are frequent upon maples after the manner of those described for apples. They are due to a killing of unripened tissues by premature freezing and are only preventable by avoidance.

MILLET

Leaf-Spot. Leaves of millet, dying from small, light-colored spots, were recently examined. These spots are due to a fungus (*Piricularia grisea* (Cke.) Sacc.) and the dying may at times be enough to shorten the yield of forage.

Smut. The seeds of millet are often attacked by the millet smut fungus (*Ustilago Crameri* Kornicke) which transforms them into black masses of smut spores, much after the manner of stinking smut in wheat. This is liable to injure the feeding value of the millet, although it is not likely that the smut will injure stock when millet is fed in the usual quantities. All smutted grain, of course, is ineffective and useless, and the smutted seed when again sown will produce a smutted crop. The smut is prevented by the same hot water seed treatment as that applied to prevent oat smut. In experiments conducted by the Botanist of this Station this treatment was successful.

MULBERRY

Bacterial Diseases. Russian varieties of mulberries have new growths, especially new sprouts attacked by a bacterium. These deep dark lesions result in cankers and all the various phenomena of the plant's effort to heal a wound in the wood. The trouble is so difficult to handle that where Russian mulberries are badly attacked, rejections may be necessary.

Leaf-Spot. Mulberries are at times attacked by a leaf-spot (*Cercospora moricola* Cke.) but this is rarely serious in our district.

MUSKMELON

Anthracnose. The common anthracnose fungus of the muskmelon (*Colletotrichum Lagerarium* Pass.) is the same as that of the cucumber. It attacks the stems of plants of all sizes as well as the leaves, resulting in the lesions of the stem and dead spots in the leaves. In these the fungus produces the fruiting bodies. After the seedling stage is passed it is usually possible to keep the anthracnose in check by the spraying as recommended for cucumbers.

The fruit anthracnose of the muskmelon (*Colletotrichum oligochaetum* Cav.) is widely distributed and has occurred with us. It forms yellowish, diseased spots on the fruits and may disfigure them considerable. It is too soon with us to estimate possible losses from it. Thorough spraying with Bordeaux mixture should hold it in check if begun on the young fruits and repeated once or twice at intervals.

Black-Spot. In 1908 a case of black-rot or spot-rot of muskmelon fruits was reported with specimens. The spots were depressed and accompanied by decay. No definite causal organism was determined, although one or more were present in the spots. It is believed that spraying will hold it in check but the case was referred to us to late to test this.

Downy Mildew of muskmelon is caused by the same *Plasmopara* fungus as the downy mildew of cucumbers. As we have the fungus in Ohio it does not appear until towards the middle of August, but is then very destructive, sweeping rapidly over the melon fields and leaving only devastation behind. In its attacks the spots of the muskmelon leaves are somewhat different in shape and usually of a darker color than in the case of the cucumber. One with experience can readily distinguish by the use of an ordinary hand-glass. He will then see on the under side of the leaf the violet spores and spore-bearing

threads of the mildew fungus. The melons which are unripened upon the vines when attacked by mildew are practically worthless and for this reason large losses are usually incurred. The treatment is by Bordeaux mixture, as for cucumbers.

Muskmelon Leaf Blight is a disease more or less peculiar to the muskmelon, although the fungus (*Alternaria sp.*) which causes it has also been found upon cucumber leaves. The leaf blight causes rather large dead areas in the leaves which are usually distinguished from those of downy mildew by their larger size and the tendency of the central portion to break out. The prevention of muskmelon leaf blight is by no means an easy matter, requiring of itself great thoroughness and carefulness in the application of the Bordeaux mixture and also requiring that the downy mildew shall be watched during the same period. For this reason earlier sprayings, if made before August 1st, should be repeated at fortnightly intervals, while those after August 1st should be at weekly or ten-day intervals. Melon growers have succeeded by following these lines, while others who were less thorough were less successful, or failed entirely. The treatment is recommended with confidence. (Bulletins 73 and 105).



Fig. 58. Muskmelon leaf attacked by leaf blight. The dead spots are caused by a species of *Alternaria*. From Bulletin 73.

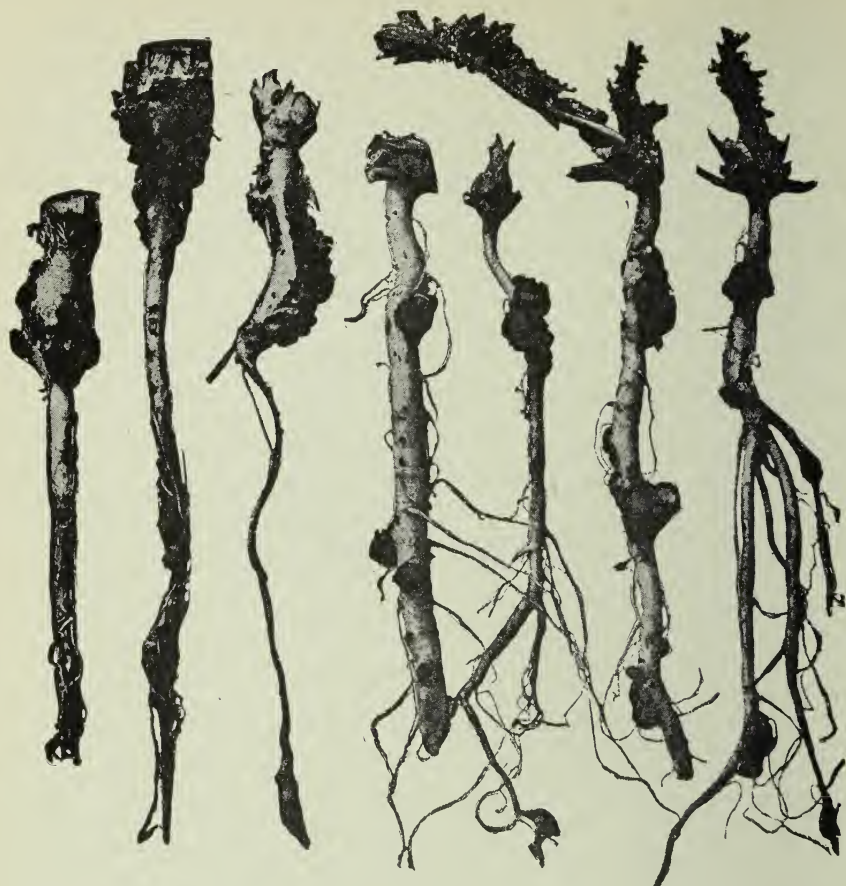
Root-Rot. (*Rhizoctonia*) The root diseases accompanied by rotting of the rootlets and induced by the sterile fungus of lettuce rosette is also found on greenhouse muskmelons. This is liable to be the case where these follow diseased crops of lettuce. The prevention is the same as that for the cucumbers, viz., thorough soil treatment.

Muskmelon Wilts are the same in general character as those described for the cucumber. Not only the bacterial wilt disease but the wilt due to fusarium has developed upon muskmelons in this state. The symptoms are the same as for cucumbers, namely: sudden wilting as from lack of water, followed by dying. The prevention treatment is the same as before recommended.

MUSTARDS

Black-Rot. Mustard plants of all species are liable to be attacked by black-rot and if permitted to grow as weeds in fields devoted to cabbage growing and will carry the black-rot trouble through the rotations in spite of the grower's other efforts. Let no mustard weeds survive in such rotations.

Club-Root. Mustard plants generally are attacked by the club-root fungus (*Plasmodiophora Brassicae* Wor.) when this is present in the soil. For this reason the weeds of several species may be infested upon lands that have never been brought under cultivation. Due attention should be given to mustard plants in new lands when designed for cabbage.



Figs. 59-60. Figure 59 on the left shows roots of shepherd's purse. Figure 60 on the right, roots of hedge mustard. Both are attacked by club-root. Both after Halsted. Bulletin 98, N. J. Exp. Sta.

Downy Mildew. The downy mildew fungus of crucifers (*Peronospora parasitica* (Pers.) (De By)) is so universal on plants of the mustard family that it may be usually expected. The weedy species may accordingly keep up the supply of the parasite which attacks cabbage and cauliflower as well as others of the family.

Wilt. It is very necessary that search be made as to the survival of the fusarium of cabbage wilt on mustard weeds.

OAK

Anthracnose. The oak leaves are attacked by the same anthracnose fungus as attacks the leaves in young shoots of sycamore and maple, but this is not so prevalent upon oaks in Ohio as upon the sycamore.

TIMBER ROTS

Wound or Timber Rots of oaks are as yet imperfectly studied and call for thorough investigation before many statements can be made for us.

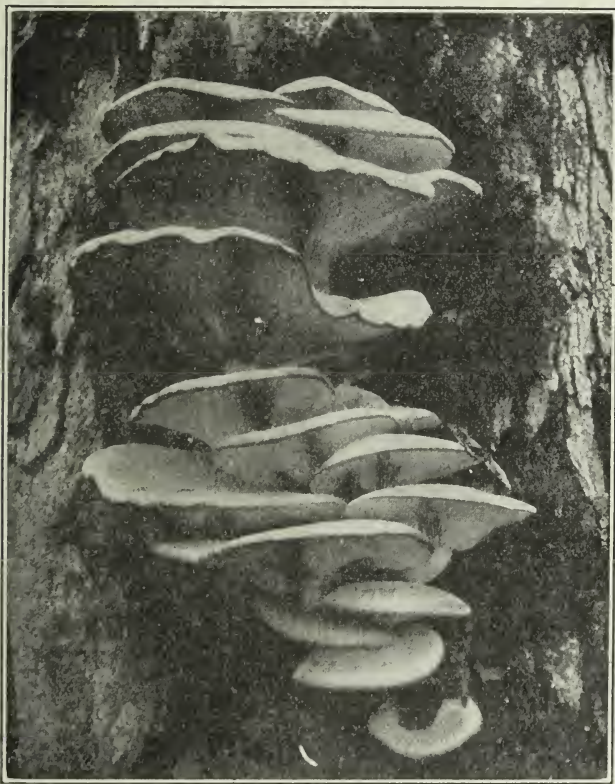


Fig. 61. A wound parasite (*Pleurotus ulmarius*) on the trunk of a maple tree. (After Freeman, Minnesota Plant Diseases).

OATS

Anthracnose (*Colletotrichum cereale* Manns.) is a new disease of oats which attacks the roots and basal portions of the culms together with the lower sheaths. The attack may extend even further than has yet been determined. The spores of this fungus were found adhering to seed oats of the crop of 1907 and the outbreak of the disease was studied in 1908. It shows by the development of the characteristic dark masses or acervulae of the anthracnose fungus upon the lower joints of the stem, portions of the root and leaf sheaths.

The amount of loss resulting from it is liable to be variable since it acts by general reduction of vigor and reduced filling of the grain head. Treatment with formalin as for smut will certainly kill the adhering spores on seed oats. (See bulletin 203).

Blade Blight. A disease similar to that earlier described as bacterial disease of oats (see Journal of Mycology, VI; 72) has been very serious in Ohio during the seasons of 1907 and 1908. The phenomena are those of yellowing and dying of older leaves associated in most cases with the presence of an abundance of leaf sucking insects such as aphids, mites and leaf hoppers. Recent culture and colonizing studies made at the Station show the disease to be due to two specific bacteria working together. (*Bacillus avenae* Manns.) (*Pseudomonas avenae* Manns). These have been isolated and described. These bacteria are carried or transmitted by the insects or are scattered by natural agencies. In control work in cages the organisms caused infection through the punctures of the aphids (green flies). Evidently the control of this disease will involve thorough seed treatment together with possible field checking of the insects distributed. (See bulletin 210).

Rust. In addition to the two species of rust found upon wheat and to be given under that grain, there is a rust common upon oats (*Puccinia coronata* Corda.), usually prevalent during the rainy harvest weather and more or less at all times. No remedy is as yet at hand.

The Scab Fungus of the oats (*Fusarium roseum* Lk.) is the same species as for wheat and attacks the panicles near filling time. It results in empty hulls with the pink fungus. The disease also survives apparently as an internal infection of oat kernels and is capable of destroying young seedlings after the manner described for wheat. (See diseases transmitted in the seed and also wheat). Like that disease in wheat, it must be controlled, if at all, by a combination of seed treatment for adhering spores and thorough seed recleaning to exclude all light kernels.

Smut. The smut of oats takes on two forms, the loose smut (*Ustilago Avenae* Jens.) and the hidden smut (*Ustilago Avenae laevis* (Jens.) Kell. & Swing). The first, which is the more common, converts the entire head, including glumes, into a sooty mass of smut spores (Fig. 62); while in the hidden smut the enclosing glumes remain about the smutted grain. No other essential difference has been found between them. Both are caused by spores from smutted seed, or seed from smutted grain, and both are successfully prevented by seed treatment with hot water or formalin as per scheme given elsew here. (See calendar and also Bulletins 64 and 97). An increase of yield beyond smut prevention has usually followed seed treatment. This alone pays for the cost of treatment and the saving from smut loss is clear profit.



Fig 62. Head or panicle of oats destroyed by loose smut. All the oats kernels and many of their surrounding parts have been converted into black, soot (smutty) masses by the loose smut fungus *Ustilago*.

OAT-GRASS

Anthraxnose. The same anthraxnose fungus (*Colletotrichum cereale* Manns.) before described as attacking blue-grass, chess, oats, wheat, rye, etc., also occurs upon oat-grass. It is less liable to cause serious injury here than on the cereal grains.

Smut. There has been at the Station a smut on tall oat-grass (*Arrhenatherum elatius* L.) which closely resembles loose smut of oats but is, in fact, a separate species of smut whose mycelium survives in the rootstocks of the oat-grass (*Ustilago perennans* Rostrup.). The smut is thus continued in the same plants from year to year. It is not clear whether the smut would be transmitted in new seed, but there is some danger, at least.

ONION

Bacterial Disease. See heart-rot below.

Blight. Leaf blight or scald of onions during mid-season, when the weather is warm and dry, is rather a common occurrence. This was especially noticeable during 1898 and 1899. While often attributable to insects, species of fungi, especially molds (*Macrosporium Sarcinula parasiticum* (B.) Thüm—*M. Porri* Ell.) were abundant in the seasons named. It may be possible to check these molds by spraying.

Fusarium Blight. This is often serious on young onions in old soil and is the forerunner of heavy losses from soft rot in storage.

Downy Mildew (*Peronospora Schleideniana* D'By.) is likely to occur upon onions, although it has not been seen in Ohio by the writer. The treatment would be as for downy mildew of other plants.

Dry or Black Neck-Rot is the most serious disease of white onions in Ohio since the losses are so very large from it, particularly in Hardin County. The white onions are grown for somewhat special markets and it is the custom, at present, to gather early before the tops fall over, to top at once, and put up in crates in order to preserve the white color of the onion. As a rule this is not practiced with black, red and yellow sorts, so that this neck or dry-rot is not so common with them. Preliminary investigations have been made of this trouble and it appears to be clearly different from the smudge fungus which also disfigures the exterior of white onions. The fungus of dry-rot or black-neck (*Sclerotium cepivorum* Berk.) requires further investigation. (See Sorauer Pflanzenkrankheiten third edition, II 302-3). In Ohio onion districts the losses are very serious between the gathering of the white onions and time for winter storage while the crates are piled in buildings or in covered ricks in fields.

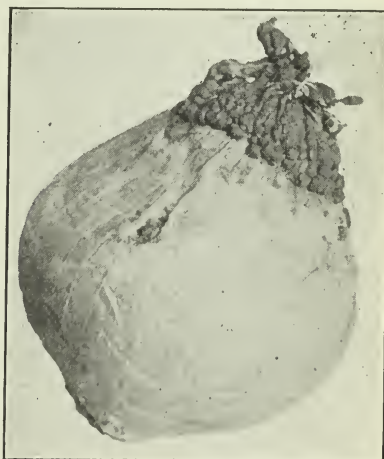


Fig. 63. A white onion that has been destroyed by a blackneck or dry-rot fungus, *Sclerotium cepivorum* Berk. This parasite has entered the onion through the green neck which was cut off at the time of harvesting the crop, (From a photograph by T. F. Manns).

It appears at this time that the early topping of the white onions, leaving a green neck, offers an inviting way for the disease to enter; that the invasion is in this direction appears from the sclerotia of the fungus which forms in this region. (See illustrations). The disease appears to grow worse with continuous cropping of onions and the losses have recently been so large in storage as to render storage of white onions unprofitable. It has been suggested by this department that the white onions should be gathered and ricked in crates at once, either in buildings or covered with tent or temporary enclosure of building paper and disinfected or treated with formaldehyde gas as per the spray calendar. (See formula elsewhere). The enclosure should not be opened for 24 to 48 hours after treatment. In this manner it is hoped to keep down the infection of the white onions as well as of any others from similar troubles.

Heart-Rot. (Bacterial). This disease has been under investigation and appears to come in all varieties of onions, following the topping, by its rapid invasion of the center of the bulb through bacterial infection. It should be controlled by attention to disinfection of the topping machine or to similar treat-

ment to that recommended for dry-rot. This disease ends in the complete destruction of the bulbs through a soft rot different from that described under soft-rot.

Smudge. This fungus (*Vermicularia circinans* Berk.) develops as a superficial spotting upon the exterior, especially attacking the white varieties; it is really an anthracnose of onions. For some time, because of its coincident development with the black neck or dry-rot, these two troubles have been confused. It is now apparently

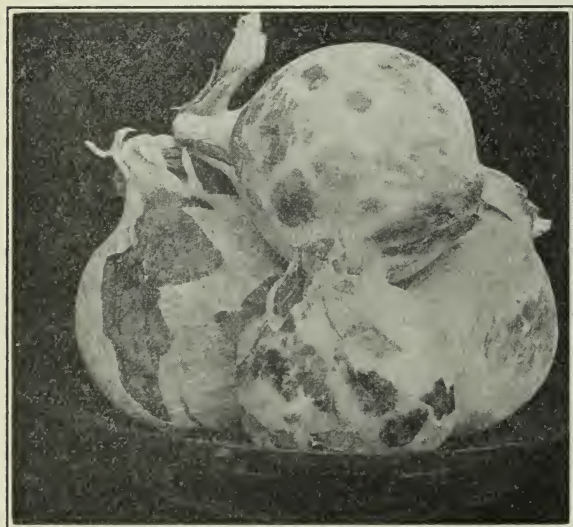


Fig. 64. Onion spotted by the smudge fungus. This fungus becomes very bad in land where successive crops of onions are grown. The fungus is also a factor in causing dry-rot of onions and set onions.

clear that there is no connection between the two, although this fungus causes dry rotting of sets and bulbs. The smudge fungus is cumulatively worse on old land where onions are grown consecutively. Apparently also in addition to rotation of crops the formalin drip treatment described under smut gives good results in keeping down this fungus. In field experiments made heretofore, the onions have been lost in storage from the dry-rot and the smudge disease has not been studied very fully in storage; apart from this it is believed to have little or no connection with the commoner storage rots, although the disfiguring effects of badly spotted onions reduce their market value, and rotting does take place as a result of it. The illustrations give characteristic appearances of these compared with healthy onions.

Onion Smut, on the other hand, is prevalent to a considerable extent in Ohio, and is one of the most destructive of the smut fungi known to pathologists. This onion smut (*Urocystis Cepulae* Frost) unlike the other smuts with which we have to do, propagates itself almost indefinitely in the soil when this once becomes infested. Whenever a new crop of onions is grown from seed in this infested soil the smut attacks the young seedling onions, in whole or in part, and a very considerable loss results therefrom. If, however, onions sets are put in such soil, or seedling onions that have been started under glass in healthy soil are transplanted to smut infected soil, the smut fungus cannot attack them. The explanation seems to be that the smut threads are only able to penetrate the leaves of the young, tender seedlings. This onion smut is now known to occur in fields at Berea Perry, Madison and near Chillicothe. At the latter place it has seriously embarrassed some of the growers of onions for sets; for this work transplanting is, of course, out of the question. In Connecticut Experiment Station Report for 1889, it is stated that flowers of sulfur have been used to sow with the seed in infested soil, and this remedy has given but slightly inferior results to any other yet tried at this Station. Forty percent formaldehyde, known commercially also as formalin, has given better results than sulfur in 1900.

At Berea, Chillicothe and latterly at Madison,

experiments have been conducted to determine a practicable field method for smut prevention. The best method has proved to be that of formaldehyde drip with seeder. (See bulletin 131). The formaldehyde solution is made at the rate of one pound of 40% formaldehyde to 25 to 33 gallons of water. This is applied with drip attachment on seed drill at rate of 125 to 150 gallons per acre for field onions. The same results can be obtained in open furrows by applying solution with sprinkler after seeds are scattered until well moistened. This formalin treatment insures the disinfection of a layer of soil near the seed and permits the germination and the early growth, of the seedling onion, past infection stage, before the smut fungus can again occupy this soil. The gains from this treatment, both in the onion set work and in field onions are very large, amount-



Fig. 65. Sound and smutted onions, gathered in midsummer. The healthy onions were grown on badly diseased soil by the use of Formalin Drip treatment.—From a photograph by T. F. Manns.

ing to 100% to 200% increase. This method has recently been applied successfully in the Connecticut Valley by a representative of the United States Department of Agriculture.

Soft-Rot and Storage Rots. The Assistant Botanist has recently studied a soft-rot (*Fusarium* sp.) of onions which shows in field, but more seriously in subsequent storage. This soft-rot is produced by the fungus *Fusarium*, yet under study. It not only causes an early blight but also invades the onion bulbs quite rapidly after storage infection. The problems of control are essentially those of storage rots including dry-rot.

In onion storage it seems to the writer probable that disinfection of the onions after placing in storage buildings either by sections or otherwise: using the formaldehyde gas treatment will give excellent and safe results. This needs yet to be worked out.

ORANGE

In greenhouses oranges are frequently grown and complaints come to us as to the troubles upon them. The chief of these troubles is a black mold (*Capnodium citri* Berk. & Desm.) on the foliage and at times upon the fruit. Spraying with fungicides has usually brought satisfactory results and develops no special injury to orange foliage.

Fruit Rots. Orange rots in stored fruits are often brought to our attention, but do not properly belong to our state work. They are the result of mold attacks following bruising. The blue mold fungus (*Penicillium glaucum* Link.) and the green mold fungus (*Penicillium digitatum* (Fr.) Sacc) are both common. These are described in other publications. (See Bul. 8, Bureau of Vegetable Pathology, United States Department of Agriculture, also Bul. 184; Calif. Exp. Sta.).

ORCHARD-GRASS

Anthracnose. Orchard-grass is attacked by the same anthracnose (*Colletotrichum cereale* Manns.) as attacks wheat, rye, oats, blue-grass and timothy. The development is shown in a similar way by the black masses of the fungus upon the basal portions of the culms and sheaths.

PALM

Leaf Diseases. Frequent complaint is made of palm leaf diseases in conservatories; the department has been able to study these but little and finds more often that they are the result of over-watering. Several diseases have been reported on palm leaves. Among these we have an anthracnose fungus (*Gloeosporium Allescheri* Bres.) of Kentia. Dr. Trelease has reported upon another fungus on Phoenix (*Exosporium palmivorum* Sacc.). This also attacks the leaves causing ultimate death. Another leaf disease is described from Europe upon Chamaerops (*Graphiola Phoenixis* (Mong.) Poit.). It is caused by a fungus which is not infrequent on the date palm. Sprays such as Bordeaux or Lysol are recommended for these palm leaf diseases.

PEA

Anthracnose. The anthracnose or pod-spot of the pea (*Ascochyta Pisi* Lib.) often develops into a serious blight of field peas grown for canneries. This was studied by the department and it was found that the anthracnose fungus infects the seed peas so that these when planted give diseased seedlings and the consequent loss of crop. (See Bul. 173). The illustrations will show how the fungus spots the pods and thus has an opportunity to enter the developing

seed peas. It was shown by spraying experiments with Bordeaux mixture that healthy seed peas may be grown. The growth of healthy peas for seeding disposes of the problem of anthracnose.

Leaf-Spot. Other leaf-spots besides those of the anthracnose are sometimes found upon the pea and are apparently caused by another fungus (*Septoria Pisi* West.) These, if giving trouble, will be controlled by the spraying for anthracnose.

Powdery Mildew (*Erysiphe communis* Wallr.) The mildew fungus often attacks the pea and at times entirely destroys its fruitfulness. It may be known by the whitish coating produced upon the leaves and by the dark, pin-head spots of the fungus observed to be situated in these white coverings. The same fungus likewise attacks the bean. For either plant spraying with Bordeaux mixture, as per directions in calendar, will be found beneficial. The first applications should be made promptly.

Wilt. A wilt of pea, apparently allied to that of cow pea and other forage crops of the south has been referred to a species of fungus *Neocosmospora* (*Fusarium*). As yet it has not been especially studied in Ohio.

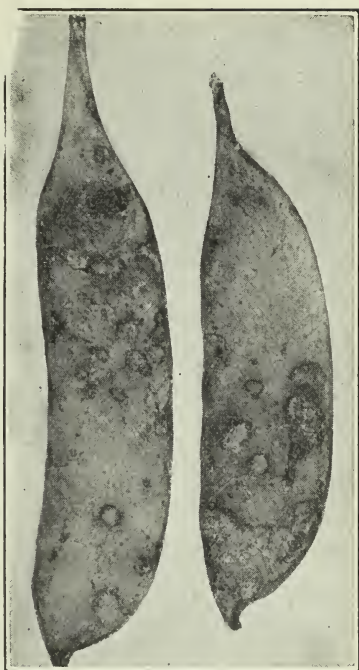


Fig. 66. Pods of French June field pea spotted by anthracnose. After Van Hook, Bulletin 173.



Fig. 67. Leaves of pea showing spots caused by anthracnose fungus-slightly magnified. After Van Hook, Bulletin 173.

PEACH

Anthracnose. An anthracnose fungus (*Gloeosporium laeticolor* Berk.) has been described upon the fruit of peach and has been found in Ohio, though rarely. Careful spray treatment as for scab should be successful against this disease.

Crown Gall. This is a very contagious disease of the peach and of other plants, notably daisy, raspberry, and blackberry, due to a bacterium (*Bacterium tumefaciens*). Sometimes it produces excrescences and enlargements upon the root and branches of the affected plant. More commonly the galls are found upon the stems just below the surface of the earth. These vary in size and in location, even occurring upon the small roots, and less frequently upon the stem at some distance above the ground. In some recent experiments (Bulletin 104) it was found that the gall trouble became communicated from diseased raspberries to peach trees set in the plantation. In some instances the loss from crown gall

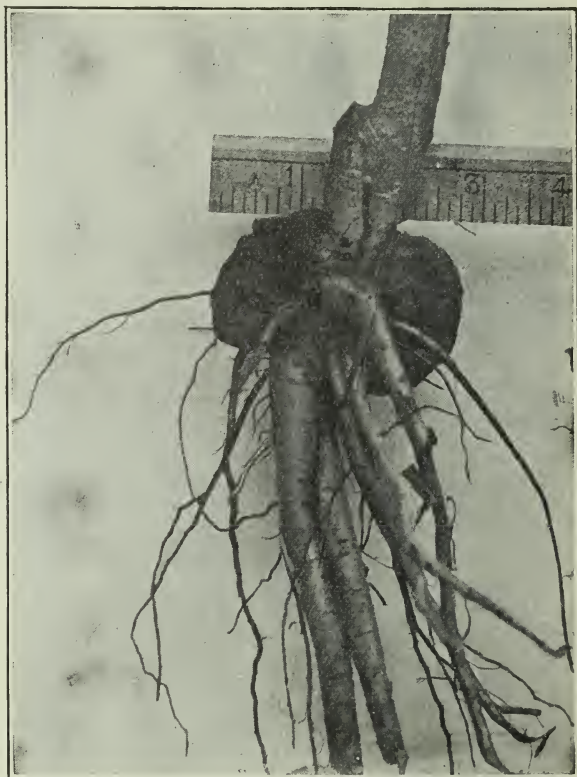


Fig. 68. Root of nursery peach tree attacked by crown gall.



Fig. 69. Crown gall attacking stem of peach tree.

has been large and there is, in my judgement, no other disease common to several of our fruit trees that is so threatening in its ravages. The peach trees attacked in most cases perish without producing fruit. This applies when the trees are affected at nursery age—the usual condition. Purchasers cannot afford to set such diseased trees nor nurserymen to ship them. As yet the only treatment that we can recommend is to dig out and burn the diseased trees, and to avoid planting affected stock. Indeed no affected stock should be received. This, with other diseases, has been treated in Bulletins 92 and 104.

Frosty Mildew. Occasionally the frosty mildew fungus (*Cercospora persice* Sacc.) occurs, whitening over the under surface of the leaves. As yet it has not been a serious disease.

Gum-Flow. The gum-flow diseases of the peach are frequent but have, as yet, been imperfectly studied in our state. We have no distinct gummosis, although in some varieties of peaches it would seem this is a weakness or a form of injury due to climate followed by gum exudations. Bark borer injuries produce a well-marked gum-flow.

June Drop is often named by peach growers as a specific trouble. It consists in the dropping of the young peaches during the month of June, though dropping sometimes comes earlier. The cause seems to be physiological and need not be feared where the trees have been prevented from overbearing, or protected from the effects of drought by thorough cultivation the previous season.

Little Peach is a disease much discussed in Michigan and is quite serious in the fact that the peaches on diseased trees never come to proper maturity or develop marketable character. Dr. Smith has found that the root hairs on many such trees are not healthy and thus it appears that some specific trouble is located there.

Leaf-Curl (*Exoascus deformans* B.). The leaf-curl fungus is at times one of the serious pests of the peach grower. However, destructive leaf-curl does not occur every year. The curl fungus survives as mycelium in the buds from year to year. It is therefore present each season, though possibly in varying amount.



Fig. 70. Leaves of peach attacked by leaf-curl. The attack of the fungus causes rapid cell multiplication and results in the distorted shapes. From a photograph.



Fig. 71. Eleven-year-old Elberta peach tree, unsprayed, defoliated by leaf-curl. No fruit. From Bulletin 148.



Fig. 72. Eleven-year-old Elberta peach tree, sprayed, March and April, 1903, with soda-lime-sulfur-vitriol, under direction of the owner. Foliage and fruit crop saved by the treatment. From Bulletin 148.

We have found in Ohio that serious leaf-curl comes when cool weather, with frequent rains, prevails during April, May and June. It is to the April weather that the most serious trouble seems attributable. With low temperatures and frequent rains during the early half of this month we may safely predict an outbreak of leaf-curl (Bulletin 92). During such weather the fungus develops rapidly and the new leaves are affected as they are protruded from the bud. In a modified sense the same takes place during May and in a still more limited sense during June. Successful prevention of leaf-curl is secured by thorough early treatment with Bordeaux mixture. Indeed, it appears that a spraying at any time shortly before the blossoms open is several times more effective than any application afterwards. It appears that more effective results are secured by spraying two weeks before blossoming than immediately before the blossoms open. In any event an application made just before the blossoms open is more effective than at any later date. Lime-sulfur applications for scale insects are effective to prevent leaf-curl. Whale-oil soap has also proved effective applied at this time, though not safe at much earlier dates. It is more expensive than Bordeaux mixture. (See Bulletins 104 and 148).

Leaf-Spot of the peach may be due to a variety of causes and in no cases studied have they proved destructive. One fungus (*Cercosperella persice* Sacc.) is often mentioned. These leaf-spot are illustrated and very briefly discussed in Bulletin 92.

Pustular Spot of the peach is a disease referable to a minute fungus (*Helminthosporium carpophilum* Lev.) which is apparently spread by spores that alight upon the upper surface of the fruit, flourish there and produce minute, light-brown spots, often surrounded by an angry red border. The red border is conspicuous in earlier varieties and is sometimes elevated and pustular in appearance. This fungus greatly disfigures the fruit and is very easily prevented. Three applications of Bordeaux mixture have reduced the amount of pustular spot to less than one percent; whereas unsprayed trees gave more than sixteen percent of spotted fruit, much of which was seriously damaged. (Bulletin 92).

Powdery Mildew (*Sphaerotheca pannosa* (Wallr.) Lev.) sometimes attacks peach in our state, but rarely with serious results. The attacked leaves sometimes turn white and are sometimes distorted. Spraying with potassium sulfid or self-boiled lime-sulfur would be successful.

Rot or Brown-Rot. The brown-rot fungus (*Sclerotinia* (*Monilia*) *fructigena* (Pers.) Schroet) is among the most destructive of the fungi on the peach, yielding place only at times to leaf-curl. Unlike leaf-curl the brown-rot prevails during warm, showery weather, and with such a weather period is likely to occur at any time of the year. In April, if the mummy peaches are permitted to remain on the trees from the preceding year, the fungus may affect the twigs through the blossoms and thus cause serious twig blight. It is a matter of common remark that the branches upon which rotted peaches are found often perish from the effects of the rot fungus. The survival of the fungus in these "mummy" fruits and the production of ascospores from them are well proven. No one variety seems more susceptible to rot than others, although some sorts are more liable to ripen during rainy weather and then rot worse. The



Fig. 73. Rotted and dried or mummy peaches collected on trees in spring. These mummies will produce growth of the rot fungus with showery, warm weather. They are dangerous.

control of rot demands: First, careful removal and destruction of all mummy rotted peaches in which the fungus survives; Second, thorough spraying of the trees before blossoming, as for leaf-curl; Third, subsequent spray treatment with self-boiled lime-sulfur as per calendar, may be profitable under certain conditions.

Root-Rot. In some instances, notably at Gypsum, Ohio, where peach trees were planted in a dense, clay soil, the roots often decay, apparently from the attacks of some fungus. Trees thus attacked usually perish soon. Whether the trouble is primarily due to the fungus or to the location in which the trees are grown has not been determined.



Fig. 74. Peaches of the Salway variety with one side blackened and cracked from scab. This loss is prevented by proper spraying.—From Bulletin 148.

Another root-rot has been further studied and found to be prevalent where orchards are set in newly cleared land, if following growths of oaks. The attack upon the roots show the rhizomorphs of the root-rot fungus as in apple root-rot which has later been more often noted in the west.

Rust. A rust fungus occurs upon the peach but not to a serious extent in Ohio.

Scab or Black-Spot. This fungus (*Cladosporium carpophilum* Thum.) is a serious drawback in the growth of certain varieties which seem susceptible. These are Morris, White, Salway and some other late sorts. It causes dark spots upon the fruit followed by cracking and entrance of the rot fungus with serious results. To control this disease, spraying results reported in bulletins 104 and 148 obtained by the use of dilute Bordeaux mixture were very satisfactory, but secured with some injury to peach foliage. In 1908-9 studies were made in an orchard near Brownhelm where self-boiled lime-sulfur was tested in comparison with dilute Bordeaux mixture. The results are very promising and indicate that self-boiled lime-sulfur is the remedy to be applied at intervals of two to three weeks after foliage appears.

Stem Blight. A stem blight of the peach was studied several years ago by the writer. (See bulletin 92). It is due to a specific fungus which in this instance attacked the stems of nursery stock causing a constriction, and this is

in line with the effects of the fungus described from Europe as a constriction or lacing disease. While in the case studied there was loss of nursery stock, due possibly to some injury to which it was exposed, there has been little recent trouble. Infection may surely be prevented by treatment with fungicides.

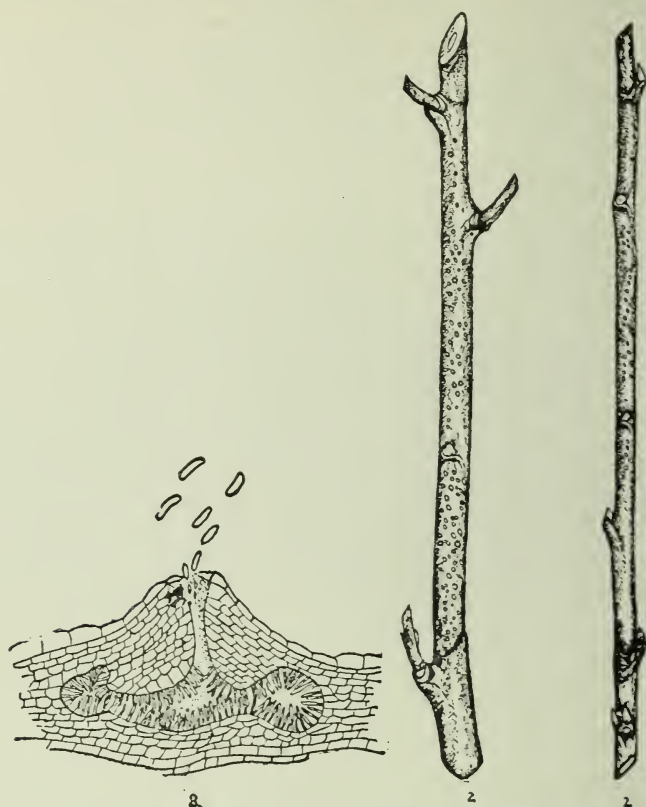


Fig. 75. Stems of nursery peach trees attacked by Constriction fungus. (*Phoma persicae* Sacc.). The trouble causes dying out of the diseased parts of the stems which are shrunk where attacked. The detail structure of spores and pycnidia are shown magnified about 500 diameters.—From Bulletin 92.

Winter Injury. In our climate the severe freezing of winter often injures the trunk and branches of peach trees. The common killing back of new growth by freezing is a familiar phenomenon. The common killing of the trunk on one side, usually the west or southwest, is also known. Many instances have been studied. Wherever there has been late growth of the trees, followed by severe winter cold, such injury may be expected. Late cultivation is therefore to be avoided. Winter injury to fruit trees may be attributed to the drying out of the trees and it is worth while to consider whether by mulching, or soil conditions, the tree may not be made to have an abundant supply of available moisture, when the upper soil is frozen hard. Much injury to peach trees from freezing occurred during February, 1899, and in the fall and winter of 1906-7. In the larger portion of these earlier cases there was more water in the soil, or about the trees, than in the less injured localities. More exposed situations also gave more injured trees. In 1906-7 the freezing was sudden upon unripened wood. (See Bulletin 192.)



Fig. 76. Peach tree, two years old, Carpenter, Ohio—one of those remaining alive though injured by freezing of 1906-7. Dead branches and ridge on trunk mark dead portion. From Bulletin 192.

Yellows. Peach yellows is a serious, contagious disease of this fruit in most portions of Ohio. Only in certain seasons may we find yellowish color as a marked symptom of affected trees. The true symptoms of yellows are: 1. Premature ripening of the fruit which is highly colored, often purplish spotted, and has the flesh marbled with red. 2. The premature growth of winter buds, resulting in excessive branching on new shoots, and the development of slender, wiry branched twigs. 3. Resting buds or adventitious buds are formed on the trunk and branches; these grow into sickly shoots with pale, narrowed leaves, and usually become much branched, with tips like veritable brooms. Aside from these specific evidences of yellows which serve to distinguish yellow color from true yellows disease, there are others less easily described but none the less useful to the practical observer. This disease may be recognized late in the

season by the late, adventitious growth. The sources of disease are diseased trees or affected nursery stock, more often the former. The remedy is to remove and to burn the yellows trees, root and branch, on the spot where found. Dragging diseased branches may spread yellows and all such trees are a menace. To leave an open hole over winter and replant the next year is a safe practice. (See Bulletins 72 and 92 for fuller discussion).



Fig. 77. Peach Yellows, winter buds of diseased tree unfolding in autumn. (After Smith, Farmers' Bul. 17, U. S. Dept. Agric.)

Recent investigations of this disease show that it is due to an enzyme which converts the leaf chlorophyll into a diseased form, causing yellows conditions. It is doubtless this enzyme which is transmitted, as in the case of tobacco, by actual contact. These discoveries have changed in no way our method of handling the disease. (See enzymatic diseases in introduction).

Rosette of peach is a disease of the southern states which appears to be similar in cause and transmission to peach yellows.

PEAR

Anthracnose. An anthracnose fungus (*Colletotrichum* sp.) occurs upon the fruit of the pear in the east, but has not been seen in Ohio.

Black-Rot (*Sphaeropsis malorum* Pk.) of the pear is the name applied to the rot like that of the quince and apple and due to the same organism. While it is less frequent as a source of fruit rot upon the pear, it is present both in this form and in the form of branch attacks or cankers.

Pear Blight or Fire Blight is one of the most serious drawbacks to pear growing. The symptoms of dead twigs and branches are well known. In substance our knowledge of pear blight is about this:—It is due to a bacterium (*Bacillus amylovorus* (Burr.) which, in the old cases of blight, winters over in the blighted parts. With April and May showers there is some exudation of watery substance from these parts, containing the zoogloa masses of the bacterium; when visited by insects these are by them transmitted to the opening blossoms. The microbe there breeds in the nectar of the blossom and in that manner attacks the branches; once within the tissues the microbe may spread indefinitely. Some varieties of pears are more susceptible, apparently, than others, which simply means that in them the microbes spread more rapidly. There is not a single variety of blight-free pear in our region. The remedy consists in cutting off and burning the blighted parts each autumn, extending the work to the crab-apple, apple and indeed to every variety of pome fruit which is attacked by this bacterium. In recent years Mr. Wm. Miller, of Ottawa County, has reported better results in blight control since he practices thorough spraying of the trees in early spring with lime-sulfur. (Bulletin 79. Year-book U. S. Dept. of Agric. 1895).

Crown Gall. The crown gall attacks the pear both at the crown and upon tips of roots. It is less rapid in its destructive effects here than upon the peach, though but slightly less serious. Enlargements may be readily detected and they are usually of denser, woody growth than upon the peach. The same remedies apply here as with that fruit.

Leaf Blight of the pear is produced by the leaf blight fungus (*Entomosporium maculatum* Lev.) which causes spotting and dying of the leaves, also cracking of fruit. The diseased leaves show a dense, dark colored coating on the under side. This disease is readily and successfully prevented by the use of Bordeaux mixture as a spray.

Leaf-Spot of pear is another fungus disease which may flourish despite the use of Bordeaux mixture, as generally applied. This fungus (*Septoria piricola* Sacc.) appears not to yield to the standard fungicides. It produces small, circular dead spots in the leaves; the spots in later summer may drop out, leaving holes. It is quite prevalent, but as yet no specific recommendations can be made for it.

Pear Scab is a fungus disease allied to Apple Scab; the pear scab fungus (*Fusicladium pirinum* (Lib.) Fuckl.) being very similar in development to that of apple scab. This fungus was very abundant in 1898. It may cause spotting of the leaves or spotting of the fruit of the pear but is not readily distinguished from the other troubles save by the use of the microscope. It is prevented by the use of Bordeaux mixture.

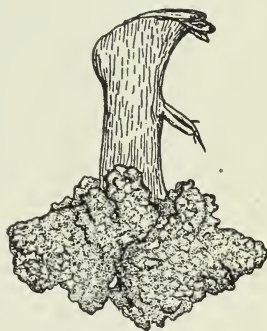


Fig. 78. Crown Gall on end of pear root.

Rust. The development of the early form of the cedar rust sometimes occurs upon pear as upon apple.

Sun-Scald is the name applied at times to the trunk injuries upon pear which are more commonly but the work of the pear blight bacterium at such points.

Sooty Disease. A sooty disease of pear fruit like that which occurs upon apple (see pages 372-3) likewise occurs upon the fruit and is also controlled by similar treatment.

PELARGONIUM

Dropsy. Some varieties of cultivated pelargonium, possibly called begonia, suffer seriously from dropsy. One bright scarlet flowered variety in particular has been cultivated at the Station. It often suffers from dead spots in the leaves. Before these spots in the leaves die, examination will show that there are wet looking places upon the under side of the leaf which appear translucent when held between the observer and the light. These are nothing more than leafcells which have become so gorged with water as to be ruptured. The break down extends to adjoining parts and then tends to produce the spots before described. This is purely a physiological trouble due to excess of water. The remedy is clear. Withhold water until absolutely necessary.

PEONY

Stem-Rot--Wilt. Frequent complaint comes to us of the dying of the stems of peony. The writer has had similar trouble. The disease has not been fully investigated. Massee and others have identified a rot fungus (*Botrytis (Sclerotinia) paconiae* Oud.) to which more or less of the stem rot may possibly be referred. The symptoms are a gradual dying of the leaves. Examination shows stems to be rotted near the ground or often very much higher. A strong, insoluble fungicide might be successfully sprayed upon the stems without covering the leaves.

PEPPERS

Anthracnose. Two anthracnoses of peppers have been described from New Jersey, as occurring upon the leaves of the plants (*Gloeosporium piperatum* (E. & E.) (*Colletotrichum nigrum* (Ells. & Hals.) although the latter may at times be found upon fruits. In addition to these Dr. Halsted has demonstrated that cultures of the apple bitter-rot as well as the bean anthracnose, will flourish upon fruits of pepper.

PERSIMMON

Leaf Diseases. So far as known to the writer no strictly fruit diseases of the persimmon occur in our district. We may have at least three leaf diseases. These are an anthracnose fungus (*Gloeosporium diospyri* (E. & E.), the true leaf-spot fungus (*Cercospora atra* (E. & E.) and a powdery mildew (*Podosphaera oxycanthae* (DC.) De By.). The mildew will show like others, as a whitish covering upon the leaves, while the others are likely to inflict real injury to the leaf tissues. All should be possibly controlled by spraying.

PHLOX

Leaf-Spot. Cultivated phlox is frequently attacked by a leaf-spot fungus (*Septoria divaricatae* E. & E.). This mars the appearance of the leaves but is not often serious.

Powdery Mildew. There is a powdery mildew fungus also (*Erysiphe Cichoraccarum* DC.) sometimes found upon cultivated phlox. It develops as a whitish covering over the leaves and other parts. Both should yield to spraying properly done.

PINE

Damping-Off. A damping-off fungus (*Fusarium* sp.) has recently been very troublesome with seedlings of white pine in the east. This has been investigated and remedies have been tried successfully. These are either dilute sulfuric acid or powdered copper sulfate and lime; the former being sprayed on the seedlings about the base and the latter applied as dust. (See Cir. 4, Bur. Plant Indus.). It is likely that with efforts to grow white pine for timber purposes in this state, troubles of this type will not be restricted to this parasite.

Leaf Blight and Leaf-Spot. Leaf troubles have been met in most areas where white pine grows naturally or is being cultivated very largely. One of these so-called leaf blights is referred to a fungus, (*Septoria parasitica* Hartig). It has been found in adjoining states if not in Ohio. Another leaf-spot fungus (*Phoma strobi* Berk and Br.) is quite prevalent upon white pine in Europe. It is believed that this parasite or a closely related one, (*Phoma strobilinum* P. C.) occurs within our borders. Remedies have yet to be worked out for these troubles.

Root-Rots are to be expected in addition to the damping-off fungus before mentioned, especially among seedling pines under culture.

Rust. In Europe the blister rust fungus (*Cronartium ribicolum* Dietr. *Peridermium strobi* Kleb.) has been long known as a serious drawback to the culture of the white pine. Curiously enough this rust has until recently not been known in the United States. Not long since warning was sent out by the Department of Agriculture that this rust had appeared in America and should be sought for upon its alternate hosts, the white pine (*Aecidia*) and the currant and gooseberry. (Uredo- and Teleutospores). Upon the pine the aecidial stage develops numerous orange cluster cups infecting the stem toward the base. This causes high mortality among the young pines. Upon the currant and gooseberry the uredospores show yellow color which darkens as the teleutospores form. These are to be sought in August or early September, and by reason of the importance of this rust merit early attention by students of these diseases.

PLUM

Black-Knot. This is the same disease as that described under black-knot of cherry. It is more frequent upon the Damson than upon the other European plums, but requires only the removal and burning of the knots each year before March, in order to grow plums successfully and without serious injury from this disease.



Fig. 79. Cluster of plums destroyed by rot causing "mummies." "Mummy" plums are dangerous whether left upon the tree or dropped to the ground, since they carry the rot fungus over the winter period.

Brown-Rot is by all odds the most serious disease with which Ohio plum growers have to deal, outranking by far black-knot, shot-hole fungus and all the other ills plums are heir to. It is the same in character as the rot of other stone fruits. As with the peach, the rot fungus (*Sclerotinia* (*Monilia*) *fructigena* (Pers.)) lives over winter in the mummy rotted plums of the year before and possibly, to a limited extent, in affected branches. The first step in successful control of rot is the removal and burning of these old plums. The next step is to spray thoroughly, before the buds open, and to continue the spraying and picking the rotted plums as circumstances demand. Likewise,

control the curculio. For details of treatment see calendar. No halfway measures will yield satisfactory results in dealing with plum rot.

Cankers. In Europe trunks of the plum as well as trunks of forest trees suffer from canker caused by a distinct species of fungus. As yet we have no true proof of cankers due to these parasites in Ohio. The parasite is *Nectria ditissima*.

Crown Gall. This disease has been reported upon the plum as upon the peach, but is less frequent



Fig. 80. Plum leaf attacked by Shot-hole Fungus. This fungus is the same as that causing Leaf-Spot on cherry, but in this case the diseased areas of the leaf tend to drop out, leaving "shot-holes."

destructive disease of the plum. It is due to the same fungus (*Cylindrosporium Padi* Karst.) which attacks the cherry, although in this case even more serious injury is liable to result than with cherry trees. Where trees are defoliated by shot-hole fungus the fruit is of small value and the trees put forth new foliage and blossoms, thus leaving immature wood and a sappy condition for trouble in winter. Under such circumstances the secondary losses may be enormous. This fungus is readily prevented by spraying with standard Bordeaux mixture, the first application being made when the leaves are half grown, and two more at intervals of about three weeks.

Winter Injury or so-called Sun-Scald. In 1896-7, following neglected cases of shot-hole fungus which defoliated the trees in the fall of '96, some plum orchards were almost totally destroyed by the severe winter freezing. The sappy trees were not in condition to withstand the severe cold,—15 degrees. Young trees were killed to the snow line while older trees had the sides of the trunk, commonly that facing to the southwest, severely injured. Plum trees were again injured by freezing in 1906-7. (See Bulletin 107). The prevention of this trouble lies in the prevention of the shot-hole fungus and the avoidance of the conditions named. In some cases it is possible that protection of the trunk by straw or boards might be profitable.

Rust upon the plum has been collected in some of the western states, but at present has not been seen in Ohio by the writer.

Leaf-curl. On Japanese varieties of plum, the leaves at times suffer from leaf-curl attacks similar to those upon peach. It should be reached by the same remedy, winter sprays.

Mildew. The powdery mildew fungus of the cherry (*Podosphaera oxycanthae* (DC) De By) also occurs at times upon the plum, but is usually rather easy to control.

Pockets or Bladders. American varieties of plum are sometimes attacked by a fungus (*Exoascus* sp.) related to the leaf-curl fungus. This causes enlargement of the young fruits which are hollow; because of this condition they are sometimes alluded to as "bladders." The conditions which bring about the disease are the same as those of leaf-curl, viz., excessive cool wet weather in the early season. The winter spray as for leaf-curl should be effective.

Root-Rot. Plums are susceptible to attack of root-rot as in the case of other orchard fruits where set following timber or fruit trees that have suffered.

Shot-Hole Fungus is at times a very de-

POPLAR

Anthracnose. Species of poplar or cottonwood are at times attacked by anthracnose (*Marsonia populi* Hals.). It produces similar effects to those of anthracnose upon sycamore.

Rust. The leaves of poplars are frequently attacked by the rust (*Melampsora populina* (Jacq.) Lev.) which disfigures the leaves by the spots caused through its development. The thrifty growth of poplars usually overcomes these foliage diseases under favorable conditions.

POTATO

Bacterial Blight. This is a serious disease of the potato; it also attacks the tomato, tobacco and egg-plant. It has been referred to a microbe (*Bacterium solanacearum* Smith). The parts of the stem attacked die off suddenly and the tubers from the affected plants have a dark discoloration of the tissues in a distinct ring at a slight distance from the exterior of the potato. Fungicides are practically useless for this disease. Such diseased tubers should not be planted nor should potatoes follow a diseased crop of tomatoes, egg-plants or potatoes. (Div. Veg. Path. B. No. 12, U. S. Dept. of Agric.)

Black-Leg. In much of Europe and in America the bases of potato stems are often attacked in the early season by a basal stem-rot which causes serious check to the growth of the plants. The diseased parts show well-marked lesions due to the work of a bacterium (*Bacillus phytophthorus* Appel.). Dr. Smith has recently investigated the disease in this country and has found it widely distributed. In Ohio it occurs to a certain extent and is at times quite similar in its effects to those referred to rosette. Measures of control will largely consist in rotation of the potato crop. See Bulletin Maine Expt. Station 174 (1909).

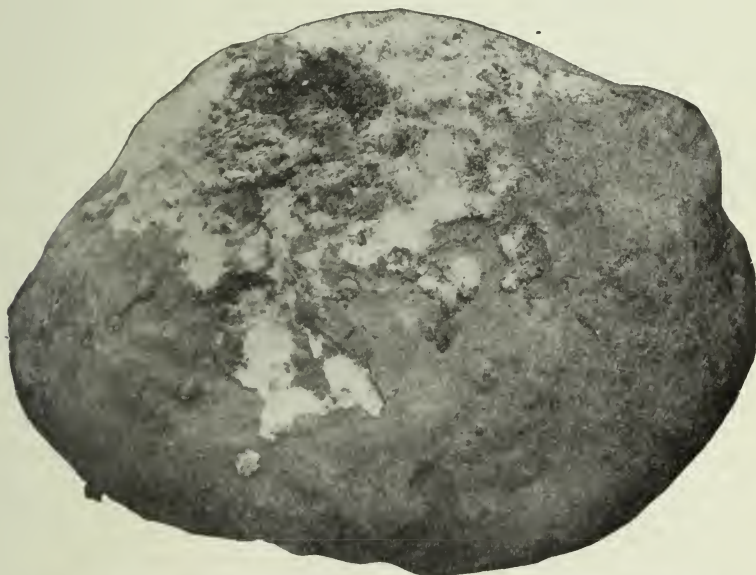


Fig. 81. A potato destroyed by Dry-Rot. This shows the characteristic appearance of the rotted potato.—From a photograph by T. F. Manns.

Dry-Rot. The dry-rot fungus (*Fusarium oxysporum* Schl.) has become generally prevalent in Ohio. This attacks the plant as the result of seed tuber or soil infection, causing wilt troubles of the plants (see Fusarium Blight) as well as dry-rotting of the tubers in storage. This tuber dry-rot is shown by the mold-like development of the fungus on the tubers. All such tubers should be rejected and rotation in potato growing should be practiced. Partly infected lots of potatoes held in storage should be promptly used. The infection of seed tubers is shown by cross sections near the stem end of the tuber at digging time or later. Where infection occurs there will be browning of the vessels near the exterior of the potato. In limited infection only small spots will show, but as the infection advances these brown tissues show as characteristic rings approaching that in bacterial blight. These spotted tissues yield the fusarium of infection in cultures as has recently been shown by the assistant botanist. Since we know that this parasite develops as a blight of the plant proper, we need to reject all diseased tubers for seed. (See Fusarium Blight).



Fig. 82. Early Blight on potato leaf. (After Jones).

Early Blight of potato is a premature spotting and dying of the potato leaves, due to the work of a parasitic fungus (*Alternaria solani* (E. & M.) Jones & Grant). The occurrence of the early blight, however, is liable to be influenced by the general vigor and other conditions of the plant; yet there is no just basis for denying, in the light of our present knowledge, the parasitic nature of this disease. Jones has made cultures of the fungus and produced the disease by inoculation (Vt. Exp. Sta. Buls. 24 and 28; Rept. 1892) and has secured most admirable results by the use of fungicides. This successful spraying in itself is in the nature of proof of parasitic character. In the potato work at this Station it has been the uniform practice to spray thoroughly with Bordeaux mixture, adding arsenites for the insects, as required, and it has been many years since we have suffered any serious loss from early blight. However, the spraying for early blight will not prevent the bacterial disease above described, and it is doubtless the confusion of these two diseases that has led to such differences of opinion among potato growers as to the efficiency of spraying with Bordeaux

mixture for early blight. There is real danger of the confusion of early blight with the Fusarium blight described in the following paragraph. Our recommendation is still that contained in the spray calendar, namely: to spray with Bordeaux mixture or some modified form of it.

Fusarium Blight. Early in the season of 1909 it was discovered that a small area of one of the unfertilized potato plots at the Station was dying out. Subsequently the area became larger and investigation showed the fungus to be that of dry-rot, which see. Later it developed that the yield of the entire tier of plots grown in three crop rotation, died prematurely although spraying had been practiced as usual. The dying plants showed infection and the dead areas had

in them black masses of a species of fungus (*Vermicularia*) whose relation to the disease is undetermined. At digging time it was found that in addition to grub injury, the tubers were very generally infected with the markings of the dry-rot fungus in the conducting tissues. Sections of the stem end showed brownish discolorations of the vessels, and occasionally tubers showed marked invasion by the fungus. Tubers collected elsewhere sometimes showed these discolorations of the vessels extending half the length of the tuber. Injury by grubs favored infection.

Following these discoveries quite thorough studies were made of potato conditions in the state, and it developed that the fusarium blight prevailed in local fields throughout the entire potato growing area. While some growers had obtained fine crops in spite of limited infection other growers had suffered seriously.

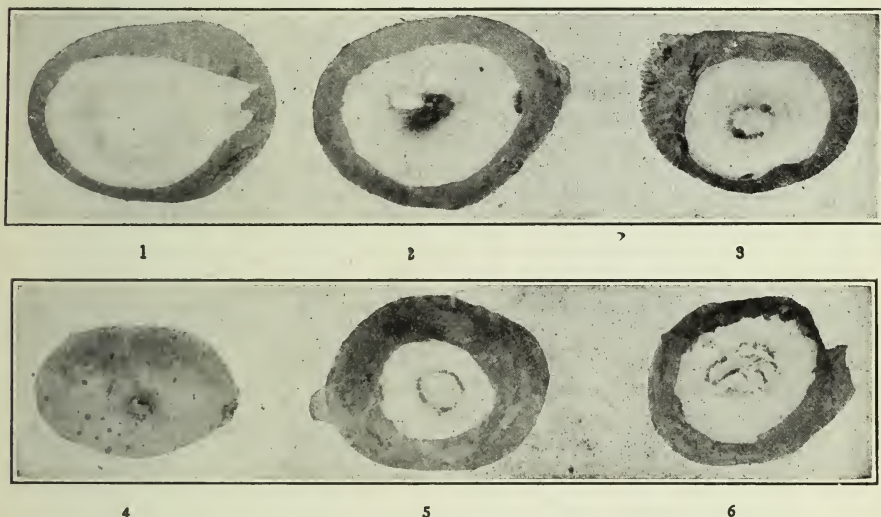


Fig. 83. Potato tubers attacked by Dry-Rot Fusarium, showing sections near the stem-end of healthy (No. 1) infected potato tubers. (Nos. 2-4) This infection may be easily discovered by cross sections made with a sharp knife, and sections from sterilized tubers give cultures in Petri dishes. At times the discolorations extend to the middle of the tuber. (From a photograph by T. F. Manns).

One grower in Summit county, who had succeeded very well in 1908 had such serious loss of crop from fusarium blight that he was led to attribute it to spray injury since blighting and dying went on in spite of the spray treatment. Investigation showed that his entire area was very badly infected with this fusarium. He was advised of the fact and warned against using infected seed or immediate planting of infected land. It developed also that northern grown seed showed up quite satisfactorily. On further examination it developed that the seed from Red River Valley and from parts of New York and possibly parts of Michigan was nearly free from infection by this fungus. It was also developed that seed potatoes stored in cellars have sometimes given much less satisfactory return than seed from the same field stored in outdoor pits. This would seem to be explained by the known fact that (*Fusarium oxysporum*) the dry-rot fungus, makes slow progress at low temperatures, that is 42° or below. This disease presents a real problem in potato growing for the year of 1910, and interpreting the results of 1908 in light of the experiences of 1909, one is led to infer that the disease then prevailed and accounted in part for the general early dying of potato tops.

In Europe, especially in Germany, in 1907 and possibly in the seasons since much complaint has been made of a similar disease to that described by Stewart as a leaf-roll disease (*Blattrollkrankheit*). In the European disease as well as in the stem blight of potatoes described by Stewart in New York (See Bulls. 101 and 138) and in our present fusarium blight, the leaves of the affected plants lose color and roll upward from the border. With this occurs a general loss of green in the plants. Orton, who has made a general study of the disease throughout the country, regards the fusarium of dry-rot as the causal organism, and finds very serious checks upon potato growing have resulted in San Joaquin county, California, upon so-called tule lands where continuous cropping in potatoes has been more or less practiced. The evidence is conclusive that we have in the dry-rot organism a blight organism of the potato plant which is at the same time a soil infesting as well as a seed tuber infecting fungus. In addition to this, incomplete observations support the idea that some spread of the organism takes place as with other fungus parasites in the field. In the matter of preventive measures and remedies, the first consideration should be given to seed tubers. These should be of such source and character as are clear from infection. This infection may easily be determined by cutting across the stem end of the tubers. Evidently cellar stored seed is dangerous during this period of epidemic. In the matter of spray prevention we have evidence in a cooperative test in Portage County, that the spray holds back the advance of the development. Upon duplicate plots where strong Bordeaux mixture was used, the gain was at the rate of 13 bushels per acre above any other sprayed plots; and 9 bushels per acre above the checks. These plots remained green longer than any of the others and show a decided reaction to the copper fungicide. From the behavior of certain hills in the various fields whose tops remained green in spite of the general infection, breeding for blight resistance should give decisive results.

Late Blight or Rot of the Potato (*Phytophthora infestans* De By) called in Europe "the potato disease" is caused by a downy mildew fungus. This mildew spots the leaves, producing a downy, felt-like covering in spots on the under side of the leaves of infested plants. This causes prompt dying with wet-rot conditions of the leaves and the tubers are rapidly destroyed with wet-rot appearances. The potato *Phytophthora* is a disease which like its host plant is accustomed to somewhat cooler conditions of climate than usually prevail in Ohio. However, in the years 1904 to 1907 all the summer months were several degrees below the normal; this resulted in continuous out-breaks of the blight or rot, culminating in 1906-7. In 1908 under warmer or drier conditions while the fungus was found at Wooster it did not inflict damage here or elsewhere in the state. It is unlikely to be injurious in Ohio, except in seasons cooler and more moist than normal. (See table of seasons page 354).

Spraying for late blight is entirely successful and should begin by the 20th of July, being repeated at intervals of two weeks and applications made at the rate of 100 gallons per acre on full grown vines. The duration of the spraying will depend upon the maturity of the plants, in the late crops reaching four or occasionally five sprayings.

Rosette. The Rosette or Rhizoctonia disease often prevails in Ohio, especially where potatoes are grown on acid soils. This acid condition is evidently favorable to the fungus which attacks the stems of the young plants or even in early developments of the stems, these are often rotted off below the surface for the earth. In later developments the elongation of the plant axis is stopped and a rosette appearance is shown in the leaves. The disease survives by the red-



Fig. 84. Showing a plant of potato affected with Rosette. The elongated injury below the soil surface shows as dark-colored in the figure.—From Bulletin 139.

Tip-burn. Potato leaves often show dead margins or tips even where no parasitic attack can be discovered. Such "tip-burn" effects may also be increased by any extra weather stress as of drouth or by spray injury. These conditions are to be met by avoiding the causes which bring them about.

Wart-Disease. This disease, also called "canker" and "black-scab" is caused by a soil infesting fungus, (*Chrysophlyctis endobiotica* Schilb) and has recently become established in New Foundland and possibly at other points in North

brown sclerotia upon the seed tubers; these are largely controlled by seed treatment with formaldehyde or corrosive sublimate. (See bulletins 139 and 145).

Potato Scab is a well known parasitic disease of the potato tuber that needs no extended description. Whether due to fungi or bacteria, or both, the practical prevention of potato scab consists in destroying the parasites on the seed potatoes and then in planting them in soil free from those organisms. The organisms in question will usually be found in soil on which potatoes were grown the previous year, or in that freshly manured. The materials used by this Station in treating for scab are two, namely, solution of corrosive sublimate and solution of formalin, as per strengths given in spray calendar. It is ineffective to treat the seed and then plant on scab-infested land. See also Wart-disease.

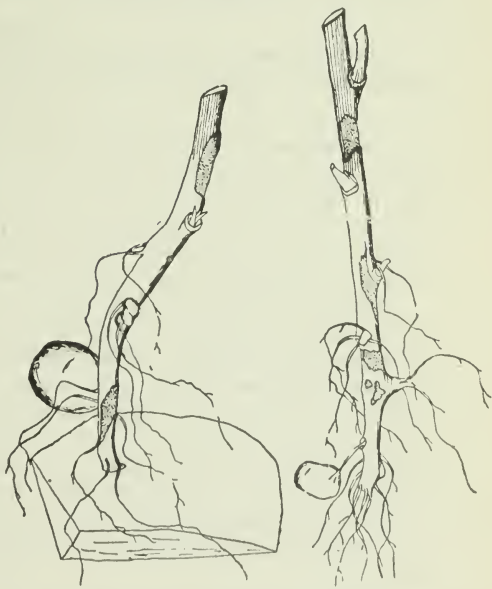


Fig. 85 Bases of potato stems showing lesions caused by Rosette Fungus. The shaded areas were dark with an abundance of the fungus, and the tops showed conspicuous Rosette effects. From Bulletin 139.

America. It was discovered upon potatoes from upper Hungary in 1896 and has since become distributed over much of northern Europe including Germany, England, Ireland, Scotland and Wales. Apparently this wart disease is the most serious potato trouble yet met with in cultivation, since it causes large warts upon potatoes but partially infected and converts those badly attacked into corky masses not unlike lumps of coke. Such tubers are entirely unfit for human food though they may be used for stock food after cooking. The fungus causing the disease survives in the potato by resting spores as well as by its vegetative parts and appears to remain as a soil infestation for five to six years. Seed treatment is not effective in controlling the disease. Every effort should be made to secure the exclusion of the disease from the United States and to recognize it should imported tubers carry the trouble. See Güssow, Bulletin 63 Central Experimental Farms (Ottawa) and Orton, Circular 52, Bureau Plant Industry 1910.

PRIMULA

Rot. A rot of Chinese primula due to *Botrytis* and similar to that on peony has been reported and may be expected with us.

PRIVET

Anthracnose. Privet in hedges is frequently attacked by anthracnose (*Gloeosporium cingulatum* Atk.). This shows itself by lesions in the younger stems and results in dying of the portions of the attacked branches beyond the lesions. This weakens the hedge and sometimes results in secondary consequences. While spraying has not been fully worked out for this disease, it should prove an effective remedy at the proper time.

PUMPKIN

Downy Mildew and Wilt attack pumpkins after the manner described under muskmelon and cucumber. The remedies are the same as there stated.

QUINCE

Anthracnose. The fruits and possibly the branches of quince are attacked by an anthracnose fungus (*Glomerella rufomaculans* Sp. & V. Schr.) which is the same as that causing bitter-rot in apple. According to our knowledge of the survival of this fungus, attention must be given to gathering and burning of "mummy" fruits and to the cankers produced, if any, upon the branches. The spraying treatment necessary is the same as that for apple bitter-rot.

Black-Rot. The fruit and foliage of the quince are attacked by black-rot. The black-rot multiplies very rapidly in the fruit of quince and often causes loss of much of that produced. This fungus (*Sphaeropsis malorum* Pk.) also develops as a leaf-spot upon the foliage causing defoliation. It is liable to attack the branches after the manner determined for apple. To hold this fungus in check very careful spraying is required at times, but as a rule it is easier to keep down the black-rot on fruit and foliage of quince than to keep it down on susceptible apples. The spray used is Bordeaux mixture.

Leaf-Spot of another kind which is identical with that upon pear is found at times controlled upon the quince. It is controlled by the same treatment as the black-rot.

Blight. The blight upon quince (*Bacillus amylovorus* (Burr.) De Toni.) is slightly less destructive than that upon pear. It is caused by the same bacterium and requires the same watchful care and attention as in the case of pear.

Pale-Rot. This (*Phoma cydoniae* Sacc.) is reported from some of our states and may occur in Ohio. There is no evidence to indicate that it will require more prolonged treatment than black-rot or leaf-spot.

Rust (*Gymnosporangium* sp.) also occurs upon the quince when trees are near cedars which carry the cedar apples and distribute spores. Labor must be devoted to the destruction of the source of infection as in the apple.

RADISH

Black-Rot, Club-Root. Black-rot (*Bacterium campestre* (Pamm) and club-root (*Plasmodiophora brassicae* Wor.) occur upon the radish at times and are of the same nature and cause as these diseases upon other mustards, especially cabbage and cauliflower. The attention to control will be similar to that for cabbage.

Downy Mildew and White Mold (*Peronospora parasitica* De By. and *Cystopus candidus* Pers.) also occur upon the leaves of radish, the latter more especially upon younger plants. These are the same diseases that have been described upon other mustard growths.

RAPE

Black-Rot, Club-Root, etc. Rape, as other mustards, is attacked by a group of diseases which are common upon plants of the mustard family. These are black-rot, club root, white mold, etc., that are more fully described under cabbage, cauliflower and radish.

RASPBERRY

Anthracnose (*Colletotrichum venetum* (Speg.) Hals.). The anthracnose fungus is a frequent bane to the raspberry grower. It attacks the young canes and so spots and injures them, as well as the foliage, that when the time arrives for ripening the fruit the plants are unable to do this and the crop is largely lost. The Horticulturist of this Station has always succeeded in holding this disease in check by use of the methods of spraying recommended in the calendar for anthracnose. Care, however,

must be used in the application of the spray to reach the stems of the young canes and to keep the fungicide from the leaves of bearing canes where it will do injury.

Cane Blight. Serious dying of raspberry canes has occurred in some of the northern districts where they are largely grown. These troubles range from "dieback" to impaired vigor in which there are seeming brown patches upon the stems. As a rule these have failed to yield a specific organism and may be the result of root conditions which appear to be quite unsatisfactory on both raspberry and blackberry, as described under the former.

Crown Gall is at present one of the most destructive diseases attacking raspberries. In some well marked cases upon the variety known as Thompson's Prolific (Bulletin 79) eel-worms have been suggested as the possible cause of the gall production;



Fig. 86. Raspberry stem attacked by Anthracnose. This causes "birds-eye" spots of the stems. After Scribner.

but whatever the cause of the galls attacking that variety we have found them transmitted to the peach in the same soil and we have found that practically all of the varieties of raspberries are attacked by a similar trouble producing like excrescences. These galls result in the destruction of the bearing canes, and where the raspberries are planted in orchards the disease, it would seem, may extend to the orchard trees as well. Late investigations show that a bacterium is the cause of crown gall on the almond. (Science N. S. Vol. XXIII, No. 575, pp. 424, 425; by Erwin F. Smith, U. S. Dept. of Agric.). Prompt removal and burning of all affected canes is the only method of treatment. Indeed it has been demonstrated from the very beginning that a healthy raspberry plantation cannot be secured by the selection of apparently healthy plants from diseased areas. Nothing remains but to secure plants from healthy plantations.

Bacterial Blight of raspberries has been described by this Station; it has not recently proved serious. (Bulletin 78).

Leaf-Spot and Rust. The leaf-spot fungus, already described for blackberries and dewberries, upon which it is more commonly found, was prevalent in 1899 upon raspberries. The only remedy for rust (*Caecoma nitens* Schw.) is the removal and destruction of all clumps either wholly or partially infected. The leaf-spot fungus (*Septoria rubi* West.) will yield to spraying with Bordeaux mixture. Winter injury usually occurs and is shown by the killing back of canes which fail to mature properly. The remedy must lie in the avoidance of the conditions.

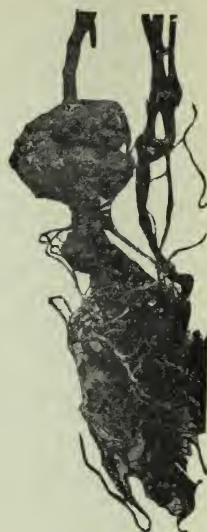


Fig. 87. Crown-Gall on raspberry plants. These also occur on the roots.

RED-TOP

Anthracnose (*Colletotrichum cereale* Manns.) was found upon red-top, as also upon timothy, orchard-grass, wheat, rye, oats and chess. The symptoms are the same as for the other grains; the disease attacks the culms and sheaths upon the lower part of the stem. The chief interest which comes from the disease upon grasses is the means this may serve to carry the disease of one rotation to the next in cereals.

ROSE

Anthracnose. An anthracnose fungus (*Gloeosporium rosae* (Hals.) attacks the rose, causing defoliation of the canes; indeed the whole plant is attacked. This behaves very similarly to the anthracnose fungus of the raspberry. Young plants are found most susceptible to the disease. The methods of handling are practically the same as for the anthracnose of the raspberry.

Crown Gall. Crown gall trouble essentially the same in character as that of raspberry, occurs on roses but requires no separate description here.

Leaf Blotch (*Actinonema Rosae* (Lib.) Fr.) often causes dark spotting of the leaves. The frost-like, branching growth over the leaf-surface is often very pretty in design though injurious in effect. If the rosehouse is too moist, or if other conditions be slightly unfavorable, the fungus seems to flourish all the better. It may be checked by the use of Bordeaux mixture or by dilute copper sulfate solution, as recommended for cucumbers in the greenhouse (One pound to fifty gallons).

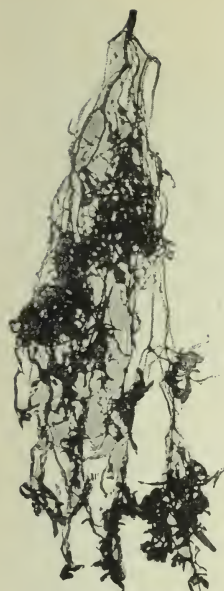


Fig. 88. Branch of rose root with Nematode Galls.

Rose Mildew is attributed to the fungus (*Sphaerotheca pannosa* Lev.) which is commonly prevalent in rosehouses; it is also found occasionally out of doors. This mildew is, for the forcing house, largely diagnostic, indicating, when prevalent, uneven temperatures. Proper attention to the matter of heat is the best preventive. Sulfur is often sprinkled upon plants and is frequently used upon the steam pipes, but it is not clear that the influence is very great.

Nematodes. Among the most serious of the rose diseases is that caused by the eelworms or nematodes which attack the roots. As with cucumbers, these parasitic worms induce the growth of small bead-like galls upon the roots of the rose. The leaves dry up from the margins, the plants generally turning yellow and breaking down as the outcome of this interference with the proper work of the roots. This subject of nematodes is discussed at length in Bulletin 73. No suc-

cessful remedy has been found for plants once attacked. The method of prevention consists, as in the case of cucumbers already cited, in the proper steaming and treatment of the soil designed for use in the rose benches.

Rust (*Phragmidium subcorticium* Schrank.). This is occasionally met and proves very disfiguring. As yet we can advise nothing more than the choice of rust resistant sorts.

RUTABAGA

Rutabaga is attacked by the same diseases as attack turnips.

RYE

Rye Anthracnose. This new disease was very serious upon rye in 1908 and was surely prevalent in 1907. The spores are carried by adhering to the seed grain and can be discovered in centrifuge separations of grain washings. In rye fields the anthracnose attacks both the heads and the lower portions of the culms. The localized attack upon the head (rachis) kills all that portion of the spike above the point of attack and the grain is but partly developed. See Fig. 90.

Upon the bases of the stems, including the roots, the fungus develops its dark masses often closely packed together and dotting both stem and sheaths (see figure). In 1908 the loss of yields in rye were from 25 to 60 percent of the total crop.

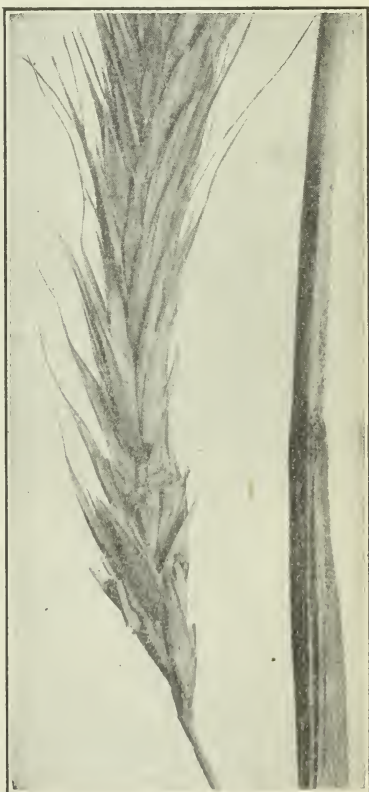


Fig. 89. Head and upper portion of stem or rye attacked by anthracnose. The point of attack upon the head is shown by the removal of the glumes; that portion above died. Upon the stem the dark spots are the acervuli of the anthracnose. From Bulletin 203.

For control of the disease thorough separation of all the light rye kernels in the seed and subsequent seed treatment are recommended. (See Bulletin 203).

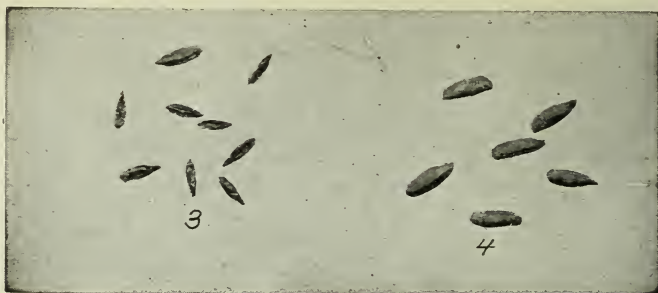


Fig. 90. On the left kernels of rye shriveled from an attack of anthracnose; on the right, normal, healthy kernels of rye. From Bulletin 203.

Ergot occurs occasionally in rye; the fungus (*Claviceps purpurea* (Fr.) Tul.) attacks the kernel and transforms it into a large club-shaped dark mass, the ergot of the druggist. The amount of ergot is usually not enough to be a serious trouble in our state. Ergotism in domestic animals is sometimes caused when diseased rye is fed to them.

Rust. The species of rust which occur upon wheat are also found upon rye. (See wheat).

Scab. The scab (*Fusarium roseum* Lk.) as is shown by recent work at this Station attacks rye almost as freely as wheat. The fungus in question is shown by recent work to be the same as that in wheat. The remedy is the same as that recommended for anthracnose.

Smut. The fungus (*Urocystis occulta* Wallr.) of stem and blade smut in rye occurred at this Station in 1909. It attacks the culms, leaves and leaf-sheaths but not commonly the floral parts. The smutted parts swell and burst open in elongated lines. Seed treatment may reduce this smut but hardly prevent it altogether.

SALSIFY

White Rust (*Albugo tragopogonis* Tul.) attacks this plant and is sometimes destructive. The best results seem to be promised by avoiding sources of infection and by spray treatment.

SORGHUM

Bacterial Blight of sorghum is somewhat similar in its general appearance to the bacterial blight of corn already described, and is caused by a specific organism (*Bacillus sorghi* Burr.). It has been described in the Kansas Experiment Station Report for 1888.

Grain Smut (*Cyntractia Sorghi-vulgaris* (Tul.) Clinton) attacks the seed of the sorghum plant. The hot water treatment may be adapted to prevent this.

Head Smut (*Sphacelotheca reiliana* (Kuhn) Clint.) occurs occasionally where sorghum is grown, but is less common than grain smut.

SOYBEAN

Wilt occurs in most districts where soybeans are grown. We have had very few reports in Ohio. Indications show that the one most likely to occur is that due to a wilt fungus (*Fusarium*).

SPINACH

Anthracnose occurs upon spinach but is not definitely known in our district.

Downy Mildew. The downy mildew fungus (*Peronospora effusa* (Lev.) Rabh.) is already known upon lamb's quarters and may appear upon the cultivated spinach of the same order. It shows as discolored or dead spots in the leaves with felted, downy covering underneath. Methods of prevention here would be as for cucumbers, except that applications could scarcely be made after the plants are nearly developed.

In older trucking districts other diseases such as white smut and scab have been reported, but are not known to occur with us in Ohio.

SNAP-DRAGON

Anthracnose. Stewart has described an anthracnose fungus of snap dragon (*Colletotrichum antirrhini* Stew.). This attacks the leaves causing brown spots and is at times serious. It may be successfully combatted by spraying with Bordeaux mixture.

Stem-Rot. A stem-rot (*Phoma* sp.) also attacks the stems of snap-dragon at any point above the ground. It is especially severe on the younger or sucker stems.

SQUASH

The squash is attacked by diseases already described under cucumber, namely, anthracnose, downy mildew and the wilts. The remedies are likewise the same.

SOLOMON'S SEAL

Leaf Diseases. Solomon's Seal is attacked by a fungus (*Aecidium convallariae* Schul.) which causes characteristic orange-colored cluster cups, and by a leaf-spot fungus (*Phyllosticta cruenta* (Kickx.). This latter disease is liable to give increasing trouble in culture.

Smut. Parts of this plant are also attacked by a smut fungus (*Urocystis colchici* (Schl.) Rabh.). I believe this is rather infrequent.

SPRUCE

Leaf-Spot. Norway spruce in Ohio has suffered seriously in 1908-9 from attacks by a leaf-spot fungus (*Phoma* sp.). This fungus causes the discoloration of the leaves (needles) also their dropping. The fruit bodies of the fungus occur upon the scales of the branches as well as upon the leaves and are evidently capable of surviving from year to year. This leaf-spot or leaf blight has been reported from several counties upon hedge plantings, upon large shade trees and upon sizes grown for Christmas trees. Drouth conditions in 1907 were a large factor in this matter causing the death of many spruce trees in 1907 and 1908. It is believed that winter and early summer sprayings will have some effect in checking the leaf trouble. This experience shows the need for mulches about Norway spruce, especially in the southern portion of Ohio.

Seedling diseases are liable to prove troublesome thus checking efforts to grow seedlings of spruce.

STRAWBERRY

Aborted Fruits. In certain seasons, and especially in 1908, there were many reports of misshapen and aborted fruits. In certain cases the salable fruit was less than 50 percent of the whole. These misshapen fruits are rarely the result of disease, more often they are the indirect result of imperfect pollination. The effects of weather conditions in hindering pollination and making it imperfect are well known. Some bright sunny weather is all essential.

Anthracnose (*Gloeosporium fragariae* Mont.) has been found upon strawberry leaves in other states; it has given less trouble than the other foliage diseases with us up to this time.



Fig. 91. Leaves of strawberry attacked by Leaf-Spot. The lighter centers have dark borders. This fungus forms ascospores in the strawberry leaves. From a photograph by T. F. Manns.

old leaves and the fungi upon them, as well as possible insects, is based upon right principles and is commonly successful.

SUGAR BEET

Crown-Rot (*Phoma betae* Frank) has been discovered in most of the sugar beet growing states and is liable to be present in Ohio in the factory district.

Leaf-Spot. The sugar beet, which is beginning to be extensively cultivated with us, has been injured by the leaf-spot fungus (*Cercospora beticola* Sacc.) and by other diseases. The leaf-spot produces small, dead areas in the beet leaves, followed at times by dying of all the leaves. For this fungus Bordeaux mixture may be applied with confidence, at intervals of three weeks. The first application should be made when the plants are about 5 or 6 inches high.

Root-Rot occurs at times, particularly upon beet seedlings where planted in rich trucking soil. The fungus

Leaf-Spot or Rust so-called is the most serious disease of older strawberry leaves. The leaf-spot fungus (*Sphaerella fragaria* (Tul.) Sacc.) matures in the old leaves. In the earlier spots on young leaves three forms of fungi are found, most of which are probably stages in the development of the leaf-spot fungus. This disease is essentially one of the season before the crop is injured. Spraying upon new plantations after picking any fruit present will usually be found profitable. The practice of burning over strawberry beds after picking to destroy



Fig. 92. Leaf-Spot trouble on sugar beet.

appears to be the same as that attacking the greenhouse seedlings of lettuce tomatoes, etc., (*Rhizoctonia* sp.) and can apparently be reached only by similar methods.

Beet Scab affects the roots of the beet as the scab does potato tubers. It is thought to be due to the same organisms. It may be avoided largely by avoiding the conditions for scab already mentioned under potato scab. Rotation of sugar beets will probably be required to escape this and other diseases.

SWEET POTATO

Bin or Soft-Rot is encountered by the sweet potato growers. The fungus (*Rhizopus nigricans* Ehrh.) producing it may be present in the plant bed and apparent as dark spots or rotted tips on the plants at setting. All such plants ought to be discarded if avoidance of disease is sought. Some experiments were made at Marietta in 1897, to prevent or reduce this rot, but without positive advantage in the keeping qualities. A dope or mixture of 6 parts earth to one part flowers of sulfur was dropped in handfuls and the plants set through the mixture thus bringing it about the roots of the plants very nicely. Smoother potatoes were obtained and these separated more readily from adherent earth, but no better keeping qualities resulted for that year. The potatoes were harvested, however, during a wet period and conditions were less favorable than is often the case.

Soil-Rot (*Acrocystis Batatas* Ell. & Hals.) is a serious disease of sweet potatoes for which the above described treatment has proved successful in New Jersey. (N. J. Exp. Sta. B. 126).

Stem-Rot (*Nectria Ipomoeae* Hals.) attacking the stems and roots has appeared in Ohio sweet potato fields, apparently introduced by affected seed. Such seed should be avoided. Rotation may also be necessary.

White Mold or White Rot (*Cystopus Ipomoea-panduranae* (Schw.) Farl.) is common upon the Man-of-the-earth and the wild morning glory (*Convolvulushederaceae*) in the sweet potato districts, but apparently is not frequent upon sweet potato foliage.

Black-Rot. This disease of sweet potato roots shows in dark, somewhat greenish spots of varying diameter. It causes serious losses in the roots and from diseased potatoes gives "black shank" in great abundance upon the young plants. The fungus (*Ceratocystis fimbriata* Ell. & Hals.) has been described as a result of Dr. Halsted's work in New Jersey. In treatment the measures are largely preventive in the choice of healthy seed, healthy sprouts and the sterilization of the plant beds.

SWEET CORN

Bacterial Disease has at times proved serious in sweet corn fields, but is apparently the same in character as that attacking sorghum, broom corn and field corn.

Smut (*Ustilago Zeae* Beckm.) also attacks sweet corn and where crops are grown consecutively in garden, the amount is sometimes excessive. The cause of it is the same as that of field corn and the conditions of control are the same.

SYCAMORE

Anthracnose (*Gloeosporium nervisequum* (Fckl.) Sacc.) is periodically very destructive on the foliage of the sycamore, extending at times to the younger shoots. The warm wet springs appear to be favorable to it; such was noticeably the case in 1908 and again in 1909. The outbreak in these years extended all over eastern United States. While the disease should be amenable to fungicides, it has been neglected.

Powdery Mildew. The leaves of the oriental sycamore, which is planted largely in Cleveland and other cities, are much disfigured by the powdery mildew fungus (*Microsphaera alni* (?). This was studied by the writer in Cleveland in 1909. It was found that younger trees were subject to attack by the mildew fungus late in the season, so that a foot or more of the tip of the shoot was disfigured by the mildew and many of the leaves were prevented from full development. The fungus does not complete its development early, and up to November 15th no spore sacs were formed. This leaves moderate doubt as to the exact identity of the fungus. It is hoped to hold this mildew in check by spraying which seems to be necessary on younger trees of the oriental sycamore.

TIMOTHY

Anthracnose (*Colletotrichum cereale* Manns) occurs upon timothy and as already noted on blue-grass, orchard-grass, red-top, wheat, rye, etc. The attacks so far studied, are confined to the culms and sheaths upon the lower part of the stems showing small dark masses of the anthracnose fungus as spots upon them. This shows that the timothy is liable to carry over the disease between the wheat crops.

Bacterial Blight of Head. See blue-grass.

Rust (*Puccinia poculiformis* (Jacq.) W) Some seasons this is very prevalent upon timothy resulting in much spotting and premature drying up of the foliage. This was true to a notable degree in Ohio in 1908.

Smut (*Tilletia striiformis* (Westd.) Wint.) attacks the blades of timothy and produces interesting developments in them. As a rule the amount of smut is not serious. (See smut of blue-grass).

TOBACCO

Bacterial Blight. The same bacterium that attacks potato, egg-plant, etc., at times attacks tobacco plants, especially in the early development. (See wilt).

Bed-Rot. Tobacco plants are often destroyed by damping-off fungi; at times even the root-rot fungus may be present in the beds. Owing to the need to use beds several years in succession for plant growing the same fungus which gives us trouble in greenhouses is very liable to give us trouble here. In the old world some of the common damping-off fungi are reported. With us our particular bed-rot troubles are due to *Rhizoctonia*. For checking this disease it seems desirable to treat the tobacco beds in late fall with formalin drench at the rate of 2 1-2 to 3 pounds of formalin to 50 gallons of water; this to be applied to beds at the rate of one gallon per square foot after spading up thoroughly and incorporating all fresh manure before the treatment is applied. The beds should also be fairly moist. After this treatment no stable manure should be applied, although mineral fertilizers can be used. If the treatments are delayed till spring it will be impossible to sow sooner than two weeks following this drench. (See Circular 59, 1906).



Fig. 93. Tobacco plants showing bed-rot, *Rhizoctonia*.

Broom-Rape. In certain infested districts in Brown county the common broom-rape (*Orobanche Ludoviciana* Nutt.) attacks the roots of tobacco, while in Kentucky the hemp broom-rape (*O. ramosa*) also occurs even to a greater extent than in Ohio. Nothing can be done to prevent these attacks of this parasite which produces its own flowers and seeds after once established. If losses are large it would be wise to rotate crops on infested land to get rid of the broom-rape.

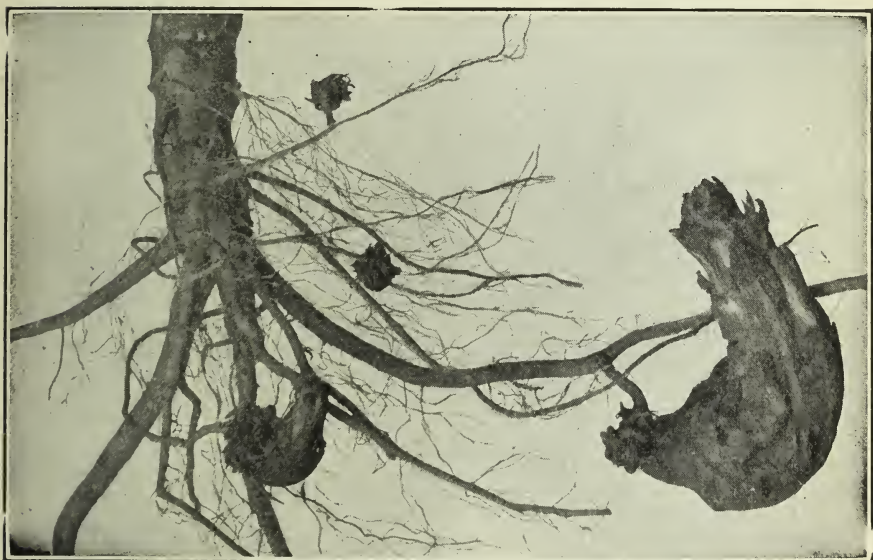


FIG. 94. Roots of white burley tobacco plant attacked by broom-rape. Each of these masses attached to the root shows beginning of the plant which will grow up in larger dense form, and produce an abundance of blossoms and seeds but no leaves. Each one of these must have started from a buried seed of the broom-rape, *Orobanche Ludoviciana* Nutt.

Curing House Troubles. At times tobacco growers have in very moist weather troubles from rotting in the curing house. These are called shed-burn, pole-burn, etc., and are difficult to control under unfavorable weather conditions. Thorough ventilation of the houses is certainly necessary where these are feared.

Downy and Powdery Mildew (*Peronospora sordida* B. & B.) and (*Erysiphe communis* Wallr.) both occur in the old world, but up to this time have not been listed in America.

Leaf-Spot (*Cercospora nicotianae* E. & E.) (*Phyllosticta nicotiana* E. & E.) occurs in some tobacco states, but is very rare with us.

Mosaic Disease also among the enzymatic diseases, is not very common upon tobacco, except in seasons when the normal development of the plants is interfered with by excessive rains and water logged soils. In Connecticut the disease is known as "calico," diseased plants showing a mottled appearance due to the alternating areas of dark green and yellowish green in them; they are

veritable mosaics. As shown a few years since by Beijerinck, Wood and others, these diseases and others of their class show a yellowing of foliage due to oxidizing enzymes in the leaves. Further as shown in experiments made in 1904, (see Bulletin 156) at Germantown, this disease is communicated from one plant to another by touching. The experiment included touching a succession of plants after touching a diseased plant; these touchings were sometimes repeated. During the period of one month there was an increase of 67 percent in those touched following contact with diseased plants. This shows the advantage of handling mosaic plants at separate times from healthy ones.

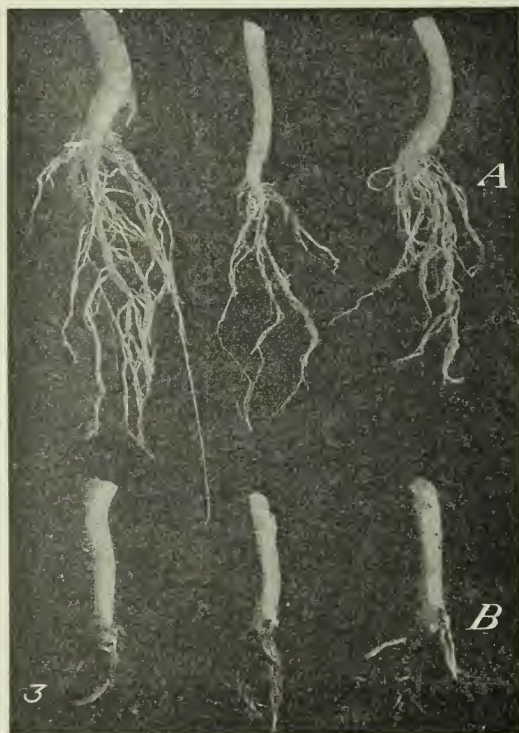


Fig. 95. Roots of seedling tobacco plants from soil inoculated with *Thielavia basicola*: A. Soil sterilized with formalin (1 to 200) and B. untreated. After Gilbert Bulletin 158, Bur. Plant Ind., U. S. D. A.

Root-Rot. Root-rot (*Thielavia basicola* Zopf.) on tobacco was first discovered by the writer upon plants received from Clermont county in 1899; since this time it has been more or less serious during wet seasons. In the vicinity of

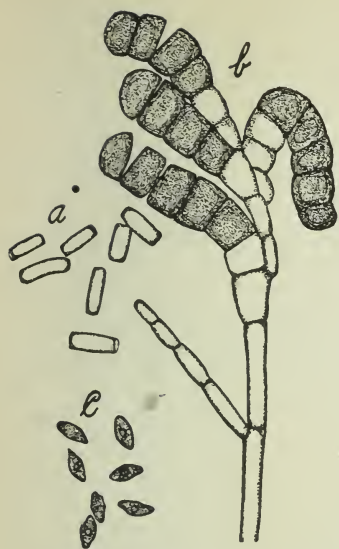


Fig. 96. The fungus of tobacco root-rot (*Thielavia basicola* Zopf.). Camera lucida drawing of the fungus as it occurs upon ginseng, tobacco and begonia. *a* and *b*, conidial forms; *c*, ascospores. All magnified 565 diameters. From a drawing by J. M. VanHook.

Hartford, Conn., notably at Litchfield, this disease has been troublesome on certain soils; the same fungus has been found upon catalpa seedlings in Ohio. It is better known as attacking the roots of violets. In all cases there is a blackening and rotting of the roots of seedling plants where they are attacked. Thorough steaming of the bed soil should be practiced where this trouble comes in, to avoid transplanting it to the field. In the field as has recently been pointed out by Gilbert and Briggs, the check on growth of tobacco is much greater in wet seasons than in dry ones. Apparently attention must be given to the drainage of the land which becomes infected if this is to be continued in tobacco.

Wilt (*Bacterium solanacearum* Erw. Smith) has occurred frequently in North Carolina and has more recently been sent to the writer from shade plantations in Florida where considerable acreage was lost in 1908, due to infection through the soil. This bacterial disease has recently been investigated by Stevens and others, but it is not believed any methods of treatment will evade the necessity for rotation. (See Bulletin 156 also potato wilt.)

White Speck has been studied in North Carolina and attributed to a specific fungus (*Macrosporum Tobacinum* E. & E.) Another fungus of the same genus has been accredited in the same state as the cause of brown-rot, but these have not been studied in Ohio.

TOMATO

Anthraxnose (*Colletotrichum phomoides* (Sacc.) Chest.) occurs occasionally upon tomato fruits, causing small depressed spots in them. The same fungus may at times attack other parts of the plant. This disease seems to be checked by the use of Bordeaux mixture. (See also Collar disease).

Bacterial Blight of the tomato, egg-plant and potato has already been mentioned. It was destructive at Mt. Carmel, near Cincinnati, in 1896 (B. 73). It has since been locally destructive. It causes sudden blighting and decaying of the stems and branches attacked. Spraying has as yet proved useless for the blight. Preventive measures recommended, include fighting insects, early removal of diseased vines, choice of fresh land not previously in potatoes or egg-plants, and tomato seed from healthy sources. To date this disease has been less destructive than the leaf-spot.

Collar Disease *Vermicularia* sp. Recently a peculiar collar disease of fall greenhouse tomatoes has come under study. In this case the symptoms were abnormal leaf development, after the manner of mosaic disease by artificial inoculation. The collar trouble was quite noticeable.

The case under study occurred in houses that appeared to be over-watered. The plants set very little fruit and were not profitable. The root system appeared to be normally developed except the adventitious whorl of roots near the surface. Between these upper roots and the root crown below, the collar of the plant

is surrounded by a development of what appears to be a parasitic fungus, a species of *Vermicularia*. The black masses of the fungus are also visible extending down upon the root bases which are lighter in color. A similar abundance of *Vermicularia* has been noted on the dead stems of potato tops which have died from fusarium blight.

This collar disease is just now under study. We believe something can be accomplished by spraying with Bordeaux mixture about the base of the plants. Certainly good will come by withholding excess water. This case of disease was described where fusarium blight and mosaic disease also prevailed. The fern-like leaf development is ascribed to the presence of the mosaic disease. The association of the two diseases may be casual.

Leaf Mold (*Cladosporium* (?) *fulvum* Cooke) is a common trouble in tomato forcing-houses in the fall or near the close of the season. It produces spots in the leaves, while beneath they are covered by the grayish-brown mold fungus. The fungicides heretofore recommended for use in the greenhouse are available for the tomato leaf mold.

Leaf-Spot or Leaf-Blight is an outdoor trouble, as is anthracnose. The leaf-spot fungus (*Septoria Lycopersici* Speg.) appears to be gradually traveling westward from the Atlantic coast, where it first appeared several years ago. During 1898 it was locally disastrous over the whole of Ohio, and again during 1900 and 1909. It may be successfully prevented by about three thorough sprayings with Bordeaux mixture, though some difficulty attaches to the treatment of unstaked tomato plants in the field. (Bulletins 73, 89, 105).

Mosaic disease attacks the tomato under conditions similar to those giving trouble to cucumbers, tobacco, etc. It is believed we have a mosaic disease analogous to that in tobacco and that the remedy is pointed out by the fact that the disease may be transmitted by touching first diseased and then healthy plants.

The symptoms of the ordinary type of the disease are the alternation of darker green and yellowish-green color in the leaves; this makes the plants conspicuous under ordinary circumstances. In 1909 with cases under glass, where the collar disease appeared to be associated, abnormal leaf forms were observed without very apparent intermixing of yellow areas in the leaves. The actual leaf forms suggested the name of fern-leaf trouble. In these specimens the internodes of the plants, the stems of the compound leaves and the petioles of the leaflets were all elongated; the leaf-blades were narrowed at times to mere borders along the mid-ribs. Gradations were also found between these extreme



Fig. 97. Tomato leaflet and stem attacked by leaf-spot. This causes dying of the leaves in showery seasons

forms and the normal leaves. Recent investigations by Westerdijk show the disease to be distinct from the mosaic disease of tobacco though doubtless analogous; the modified leaf forms were obtained by artificial inoculations both by Westerdijk and in the Pathologium of this Station by Manns.

Nematodes may be very injurious to tomatoes grown under glass. They cause, as on cucumber plants attacked, gall-like enlargements on the small roots of the tomato. Previous soil treatment to destroy the nematodes is the remedy in this instance, as in the other. It will usually occur that tomato plants are less susceptible to injury by nematodes than are cucumbers and melons.

Point Rot of green tomatoes, especially in the forcing-house, is often the most serious trouble with which the tomato grower under glass has to contend. It was stated in Bulletin 73 that this trouble was observed to be most destructive in cases of scant water supply in the soil. This observation was again confirmed by the Horticultural Department of the Station during the season of 1899. The trouble was checked by abundant and careful watering, even when it had been very bad, and was again produced by withholding water and allowing the plants to dry out. The cause appears to be largely due to conditions of drouth, and while other causes than the one just stated, notably a certain bacterium does join to produce point rot, none other appears so under control as water conditions. The remedy lies of course, in the avoidance of drouth from which the rot may indirectly result.

Root-Rot or Rosette occurs frequently in greenhouses where tomatoes are grown following crops of lettuce. The fungus produces various effects which are commonly damping off of the younger seedlings or collapse of the older ones; recently a basal constriction of the stem of mature plants is traced to *Rhizoctonia*. In this case wilting of plants resulted. It seems to be propagated under greenhouse conditions where much organic matter is used and calls for soil disinfection through steaming or formalin drench as described elsewhere under lettuce and under soil diseases. In older plants the symptoms are shortened development of the axis giving effects similar to that in lettuce.

Sclerotium Blight. This is a wilt disease first reported by Rolfs from Florida but it is now present in Ohio greenhouses. The first symptom is wilting of terminal portion of plant. The dead plants and diseased portions shows in them sclerotia of the fungus which causes the trouble. These are of the size of mustard seed or smaller, at first milk white and finally mahogany red to black. Sometimes these sclerotia grow together in anvil-shaped masses. Burning diseased plants is advised.

Wilt. A wilt (*Fusarium* sp) of tomatoes in addition to that described under bacterial disease has been discovered recently in greenhouses in Ohio as well as other states. It is due to a *Fusarium*.



Fig. 98. Stems of young greenhouse tomato plants damped off from attacks of "*Rhizoctonia*." From a photograph by T. F. Manns.



Fig. 99. Tomato fruits with browned and diseased spots in them. This form of disease results from Fusarium Wilt of the plants; also probably from Bacterial Wilt. From a photograph by T. F. Manns.

The symptoms of this wilt are rather characteristic. It may attack plants either vigorous or of slow development. Commonly the first symptom noticed is the yellowing and drying up of the lower leaves. Soon dark areas appear in the stem and also in the fruits. At all stages cross sections show darkening of vessels. The roots become darkened and watery in the region of the vessels. Eventually the top of the plant wilts and the leaves die both above and below, while the fruit has become worthless. We believe this to be a soil infesting disease that should be controlled by thorough soil sterilization.



Fig. 100. Similar fruits of green tomatoes spotted by effects of blight in Station greenhouses in 1895. From Bulletin No. 73.

TURNIP

Black-Rot. The same bacterium attacks turnips as cabbage, cauliflower and other mustards; the diseased roots show blackening of the parts with final decay.

Club-Root. This fungus organism (*Plasmodiophora Brassicae* Wor.) infests the roots of many cultivated mustard plants, including the turnip, radish, rutabaga, etc. The treatment is the same as stated under cabbage.

Downy Mildew (*Peronospora parasitica* (Pers.) De By.) sometimes occurs attacking turnip plants.

VERBENA

Mildew. Cultivated verbenas are attacked by the mildew *Erysiphe Cichoracearum* D C) which is so common on the wild vervains. It is to be treated as other powdery mildews, by spraying with fungicides.

VERONICA

Leaf Diseases. Cultivated species of veronica are attacked by several leaf diseases, which have been imperfectly studied. Perhaps the most common of these is due to the typical leaf-spot fungus (*Septoria veronicae* (Rob). There are other parasitic species which attack the genus, including a downy mildew and a rust.

VETCH

Spot. A spot disease (*Protocoronospora nigricans* Atk. and Edg.) has been described as new from New York.

The Wilt of Vetch similar to that of soy beans, cow peas and cotton has also been described.

VINCA

Leaf-Spot. The large flowered vinca is occasionally disfigured by a leaf-spot (*Sphaeropsis vincae* Sacc.) which may also develop as a stem disease. It has not been studied carefully with us.

VIOLET

Leaf-Spot and Leaf Blight (*Phyllosticta Violae* Desm. and *Cercospora Violae* Sacc.) are sometimes prevalent, and with downy mildew of violet should yield to spraying with fungicides.

Nematodes of violets are, on the other hand, not amenable to spray treatment. The parasite in the case is the same as named under cucumber nematodes, likewise its effects. Soil treatment will also be effective in prevention here.

Root-Rot. Root-rot (*Thielavia basicola* Zopf.) has not been reported as troublesome by greenhouse men in Ohio, but it is scarcely possible it can be entirely lacking when the disease occurs upon tobacco and catalpa in fields. The blackening and rotting of the roots, due to the fungus, will impair the development of the plants and the flower growth seriously. It does not seem possible that anything short of sterilizing the soil and starting new plants will check the root-rot where once established.

VIRGINIA CREEPER

Leaf-Spot. The leaves of virginia creeper are frequently curiously spotted by a leaf-spot fungus (*Phyllosticta labruscae* Thüm.) which gives dying spots with colored border. This leaf-spot is also very common upon the Japan creeper and is identical, according to recent reports, with the leaf-spot of the grape; indeed we have a large number of the well known diseases of the grape attacking the Virginia creeper. These include anthracnose, which may be distinct, the black-rot fungus, of which this *Phyllosticta* may be a stage and possibly others. This would be especially true in the vicinity of cultivated grape vines.

WALNUT

Anthracnose or Leaf-Blight. The leaves of walnut, as well as the leaves of butternut, are attacked by an anthracnose fungus (*Marsonia juglandis* Sacc.) which in common with other anthracnoses, is capable of serious injury to the leaves of these trees. It is believed that this fungus will be held in check by sprays.

Leaf-Spot. The walnut is also attacked by other leaf fungi producing leaf spots, but these have not been investigated by us in Ohio.

Mildew. The same powdery mildew which attacks a variety of trees (*Mycosphaera alni* DC.) also attacks the leaves of walnut, growing over and forming a mildew covering.

WATERMELON

With the possible exception of the wilt disease and the leaf-spots, the diseases of the watermelon are the same as those which attack cucumbers and muskmelons. They include anthracnose, downy mildew and leaf blight. The leaf-spot of the watermelon is referred to a distinct fungus (*Cercospora citrullina* Cke.) though its ravages are, possibly, not general. (See Bulletins 73, 89, 105). In the treatment of watermelon vines it is advisable to use the more dilute Bordeaux mixture, Bordeaux II, of the calendar.

WHEAT

Anthracnose (*Colletotrichum cereale* Manns). In 1907 centrifuge examinations were made by the Assistant Botanist showing the presence of anthracnose spores in the washings of shriveled wheat samples. The disease was discovered in the fields generally over Ohio in 1908 and has recently been described in Bulletin 203. This anthracnose is certainly the cause of shriveling in wheat. It appears to be the obscure trouble sought for some years by the writer. In common with other anthracnoses it develops as maturity approaches and on wheat it attacks the lower portions of the stems and sheaths resulting in apparent whitening of the spikes with decided shriveling of the grain. The fungus may be detected by the color changes in the field and by the dark spots appearing on the sheaths and stems where attacked. It is believed that thorough separation of shriveled grain by recleaning seed wheat and treatment of seed wheat with formaldehyde drench will be favorable to keeping down the amount of anthracnose. It is admitted that the presence of the fungus upon grasses and

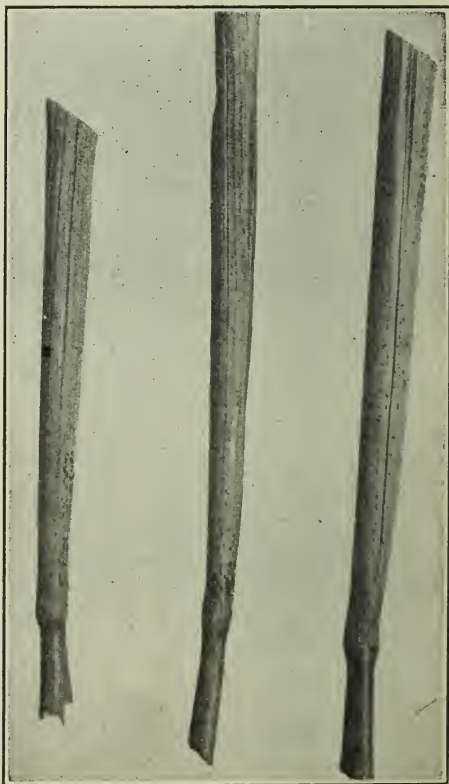


Fig. 101. Culms of wheat with both stems and sheaths attacked by anthracnose. The dark spots are caused by the fungus. From Bulletin 203.

upon other cereals increases the danger of its being carried over in rotation. (See rye, oats, timothy, also Bulletin 203.)



Fig. 102. This shows on the left, wheat shriveled by anthracnose attacks of the plants; on the right normal healthy kernels of wheat of the same variety. From Bulletin 203.

Blade-Spot or Leaf-Spotting has occurred upon wheat in considerable extent in Station plots during the last year or two. Small areas were killed by the fungus and this leads to somewhat premature dying of the leaves. This leaf disease calls for further investigations.

Grain Diseases. It must be remembered that anthracnose and scab are both in a sense grain troubles. They cause shriveling and loss of quality in the grain. In addition a fungus (*Alteraria* : „) causing dark spots in wheat kernels has been found by this department. Scab must also be included here since the parasite attacks the wheat kernels.

Powdery Mildew. This whitish fungus (*Erysiphe graminis* DC.) also appears upon leaves of wheat plants. Usually it is of small importance in Ohio but of much interest.

It attacks wheat both in pot cultures under glass and in outdoor growth. In both cultures the conidial development of the fungus is very troublesome invading the older leaves and causing premature death. In the field the consequences are usually not studied, but the perithecia of the fungus are often found upon straw blades and other parts that have been invaded. It is clear that the fungus cannot be beneficial to the development of the grain in attacked plants.

Scab. The scab disease (*Fusarium roseum* Lk) has been again investigated and the results published in Bulletin No. 203. It has been found that the same scab fungus attacks also rye, emmer, oats and spelt, producing the various effects upon these grains. On all attacked heads in wheat the portion diseased shows reddish or pink covering with the fungus and the part of the spike above this is killed. Of course, all kernels contained in that part are much shriveled and are commonly invaded by the scab fungus. In addition a recent study showed that many various sized kernels of wheat are infested with this fungus internally, although still capable of starting to grow and making a new plant. Investigations made in



Fig. 103. Wheat spike attacked by scab. The upper portion of the head is shrunk and has been killed by the pink fungus.

culture dishes and greenhouse recently, show that the fungus survives in the old dead seeds as well as in some capable of germination and attacks the seedling wheat plants during the first month of their growth. In the continuous wheat plots of the Station it was found that nearly 6 percent of the plants were killed off in the unfertilized plots during 1907; the fertilized plots show a good deal less and the rotation plots a great deal less (see Bulletin 203). Not only may the fungus survive in its perithecial form upon wheat heads, straw and dead scab grains, but it may survive in grain capable of germination as well as in the soil. See pages 334-335. Recent studies of diseases of clover and alfalfa seem to show that this same fungus is the cause of serious clover and alfalfa sickness. It would thus appear to be carried over through rotations of clover, etc. The best method of handling appears to be recleaning seed wheat and getting out all shriveled kernels which are often scab-infested as well as all under sized kernels thus evading a large share of the infection in seed wheat.

Seedling Blight. The seedlings of wheat are killed off by the attacks of the scab fungus which is transmitted in the seed as well as in the soil devoted to continuous wheat culture. (See scab above, also Bulletin 203.)



Fig. 104, On left, healthy normal kernels of wheat; on the right, above kernels injured by scab which will not germinate—below kernels injured by weevil. From Bulletin 203.

Loose Smut. This is a smut fungus (*Ustilago Tritici* Jensen) which converts grain and glumes into a sooty mass of spores. These heads of loose smut are most obvious at the blossoming of the wheat. The disease is worse on certain varieties of wheat. It may be prevented by the modified hot water treatment as per calendar.

Rust. While essentially the same to the ordinary observer, the wheat rust is produced by two rust fungi (*Puccinia graminis* Pers. & *P. rubigo-vera* D C). Only the last named passes the winter in the wheat plant. Both have the light red and the black (dark) stages and are very damaging under conditions which favor the rust. In Europe, Australia, and California wheat growers hope to select rust proof varieties of wheat. Recently in England quite an impetus has been given to wheat breeding by the work of Biffen upon resistant varieties of wheat. This resistance applies in the English studies not only to rust, but to some other features. The matter of resistance is the hope of rust prevention. (See Bulletin 97.)

Stinking Smut of wheat is caused by a still more destructive smut fungus, (*Tilletia foetens* B & C) which converts the kernels of wheat into dirty, stinking masses of spores. These,

if abundant, ruin the flour and render the wheat valueless for human food. At times 40 percent of the wheat is thus destroyed and the losses from it are often very large. Recent investigations have established that this smut is caused by the smut spores sown with the seed grain. If the smutty seed wheat is treated with a fungicide, such as bluestone, hot water, formalin, etc., which will destroy these spores without injury to the grain and the treated seed is then prevented from subsequent infection, dried and sown, a clean crop may be grown from smutted seed. For details of treatment see calendar and Bulletin 97, which treats of the diseases of wheat.

WHITE PINE

See Pine.



Fig. 105. Heavy spike of bearded wheat destroyed by loose smut. These smut spores are scattered and find entrance into the forming kernels of wheat when the blooms open for pollination.



Fig. 106. Diseased and sound spike of Poole wheat. In the one at the left the kernels have been destroyed by Stinking smut and spikelets are spread abruptly.

ADDENDUM

Corn, Root-Rot, (*Fusarium* sp.). Recently the Department has made preliminary studies of a root-rot of corn attributed to a species of *Fusarium* of similar behavior to the scab of wheat, potato fusarium and cabbage wilt, in that the parasite appears to survive in the affected soil, as well as elsewhere. From Fayette county comes the report of diseased corn roots in patches where the stalks blow over easily, and rarely form mature ears. Roots of such plants are partly killed and thus weakened. At present we can only advise rotation of crops. More knowledge is needed with all this type of soil infesting diseases.

Raspberry, Cane Blight (New York). In reference to cane blight conditions, page 437, this specific disease described by Stewart (Bul. 226, N. Y. Agric. Expt. Sta., 1902) was not mentioned. Stewart identified the disease on specimens sent to him from Ohio in 1902. Recently other specimens have been received from Cuyahoga and Wood counties. The earlier reference to cane blight forms indicates how serious the raspberry condition is in Ohio. The parasite causing the disease is *Coniothyrium Fuckelii* Sacc. The fungus attacks the plants killing and discoloring the bark and wood, thereby causing wilting of bearing canes, and the ultimate death of the parts that have been attacked. The foliage on affected canes wilts suddenly and becomes dry. The whole cane may be involved, or only a part of it. At times a single branch is killed, while the remaining cane continues apparently normal. It is feared that this disease is very common in our unprofitable raspberry plantations in Ohio. The disease is doubtless disseminated in plants from diseased plantations, and by the ordinary agencies of wind, rain, etc. Naturally the dissemination by these last two agencies is local. Preventive measures will include healthy plants, planting on new uninfected land and a prompt cutting out and burning of old canes after fruit is gathered. Stewart's work indicates inconclusive results from spraying.

LITERATURE OF PLANT DISEASES REFERRED TO IN THIS PUBLICATION

GENERAL WORKS

- 1 DUGGAR, B. M. Fungous diseases of plants. 508 pp. Ginn & Co., New York, etc., 1909.
- 2 FRANK, A. B. Die Krankheiten der Pflanzen, (Diseases of Plants) 1, 2 and 3 pp. 344, 574 and 263, (3d Vol., Insect Parasites) 2d ed., Breslau, 1896; Edw. Trewendt.
- 3 HARTIG, R. The diseases of trees, translated by Somerville & Ward. 331 pp. London 1894.
- 4 MASSEE, G. Text-book of plant diseases. 458 pp. The MacMillan Co., New York, 1907.
- 5 PRILLIEUX, Ed. Maladies des plantes agricoles et des arbres fruitieres et forestiers causees par des parasites vegetaux, 1: 421 pp. 2: 592 pp. Paris, 1897.
- 6 SMITH, W. G. Diseases of field and garden crops. 353 pp. 1884.
- 7 SORAUER, PAUL. Handbuch der Pflanzenkrankheiten, 3: (3d ed.) Diseases caused by plant parasites. 550 pp. Berlin; Paul Parey, 1908.
- 8 TUBEUF, K. VON, and SMITH, W. G. Diseases of plants induced by cryptogamic parasites. 598 pp. Longmans, Green & Co., London and New York, 1897.
- 9 WARD, H. MARSHALL. Timber and some of its diseases. 295 pp. The MacMillan Co., N. Y., 1897.
- 10 WARD, H. MARSHALL. Disease in plants. 309 pp. The MacMillan Co., N. Y., 1901.

WORKS APPLYING TO PARTICULAR AREAS

- 11 FREEMAN, E. M. Minnesota plant diseases. 432 pp. St. Paul, 1905.
- 12 HALSTED, B. D. Reports and Bulletins New Jersey Agr. Exp. Sta., 1889-1908.
- 13 SELBY, A. D. A condensed handbook of diseases of cultivated plants in Ohio. Bul. Ohio Agr. Exp. Sta., 121; 1-69, 1900.
- 14 SMITH, RALPH E. Reports of the Plant Pathologist (Calif.) 1906-1909. Buls. 184 and 203: Agri. Expt. Sta., Berkeley, Calif.
- 15 STEWART, F. C. and BLODGETT, F. H. A plant disease survey of the Hudson Valley in 1899. Bul. New York Agr. Expt. Sta. 167: 273-308, 1899.
- 16 STEVENS, F. L. and HALL, J. G. Notes on plant diseases occurring in North Carolina. Rept. N. C. Expt. Sta., 1908: 66-82.
- 17 STURGIS, W. C. Literature of fungous diseases. Rept. Conn. Agr. Expt. Sta. 1893: 253-286. 1897: 182-222.
- 18 ORTON, W. A. Plant diseases in United States. Yearbook U. S. D. A. 1900: 729-731; 1901: 668-674. 1902: 714-719; 1903: 550-556; 1904: 581-586; 1905: 602-611; 1906: 499-508; 1907: 577-589; 1908: 533-538.
- 19 WILCOX, E. M. and STONE, R. E. Directions for control of Nebraska plant diseases. Rept. Neb. Agr. Expt. Sta., 22: 1909, 22-63.

NAMING PLANT DISEASES

See General and Local works listed above.

- 20 ORTON, W. A. Plant diseases in the United States in 1907. Yearbook U. S. D. A. 1907: 577-589.
- 21 STEVENS, F. L. Common names for plant diseases. Science N. S. XXXI: 747, 1910 (May 13). (See also earlier article on same subject).

DISEASE RESISTANCE IN PLANTS

- 22 GREEN, W. J. and WAID, C. W. Potato investigations. The early and late blight and how to combat them. Bul. Ohio Agr. Exp. Sta. 174: 251-289.
- 23 JONES, L. R. Disease resistance of potatoes. Bul. Bur. Pl. Ind. U. S. D. A. 87: 1-39, 1905.
- 24 ORTON, W. A. Development of farm crops resistant to disease. Yearbook U. S. D. A. 1908: 453-464.
- 25 ORTON, W. A. and WEBBER, H. J. A cowpea resistant to root-knot. Bul. Bur. Pl. Ind. U. S. D. A. 17: 38 pp. 1902.
- 26 ORTON, W. A. The wilt disease of cotton and its control. Bul. Div. of Veg. Physiology and Pathology, U. S. D. A. 27: 1-16, 1900.
- 27 STUART, WM. Disease resistance of potatoes. Bul. Vt. Agr. Expt. Sta. 122: 107-136; 1906.

METHODS OF INOCULATION FROM CULTURES OF PARASITIC ORGANISMS

- 28 SMITH, ERW. F. Bacteria in relation to plant diseases. 1: 108-109; 1905.
- 29 Buls. Ohio Agr. Exp. Sta. 203 and 210; 1909.

ENZYMATIC DISEASES

- 30 BEIJERINCK, W. M. Ueber ein Contagium vivum fluidum als Ursache der Fleckenkrankheit der Tabaksblätter-Verhandeligen der Koninklijke Akademie van Wetenschappen te Amsterdam; Deel 6, No. 5. See also Centb. f. Bakt. Par. &c., II, 5: 27-33; 1899 and Archiv. Neerl., 2 Ser. III: 184, 1900.
- 31 HUNGER, F. W. T. De mozaiek-ziekte bij deli-tabak, Deel I. Med. s' Lands Plantentuin 63: 1903.
- 32 HUNGER, F. W. T. Die Verbreitung der Mosaikkkrankheit infolge der Behandlung des Tabaks. Centbl. f. Bakt. Par. &c, II, 11: 405-408, 1904.
- 33 SELBY, A. D. and HOUSER, TRUE. The mosaic disease of tobacco. Ohio Agr. Expt. Sta. Bul. 156: 91-95, 1904.
- 34 WOODS, ALBERT F. The destruction of chlorophyll by oxidizing enzymes. Centbl. f. Bakt. Par. &c. II, 5: 745, 1899.
- 35 WOODS, ALBERT F. Observations on the mosaic disease of tobacco. U. S. D. A. Bul. Pl. Ind. 18: 1-24; 1902.

PLANT DISEASES TRANSMITTED IN THE SEED

- 36 ARTHUR, J. C. Report of the Botanist New York Agr. Expt. Sta. 1884.
- 37 BARRUS, M. F. The dissemination of disease by means of the seed of the host plant. Proc. Ind. Acad. Sci., 1908: 113-122.
- 38 BOLLEY, H. L. Scab of potatoes and beets. Buls. North Dakota Agr. Expt Sta. 4: 1891; 9: 1893; 19: 1895.
- 39 BOLLEY, H. L. A preliminary note on the cause of flax-sick soil, *Fusarium Lini* sp. nov. Proceedings Soc. Prom. Agr. Sci. 22: 42-46, 1901.
- 40 BOLLEY, H. L. Flax wilt and flax-sick soil. Bul. North Dakota Agr. Expt. Sta. 50: 27-60; 1901.
- 41 BOLLEY, H. L. The use of the centrifuge in diagnosing plant diseases. Proc. Soc. Prom. Agr. Sci. 21: 82-85; 1902.
- 42 BREFELD, O. Recent investigations of smut fungi and smut diseases. (Translated) Jour. Myc. VI: 59; 1890.
- 43 BREFELD, O. and FALCK, R. Die Blüteninfektion bei den Brandpilzen und die natürliche Verbreitung der Brandkrankheiten. Gesamtgb. der Mykol. Heft. 13: 1-70; 1905.
- 44 GUSSOW, H. T. A serious potato disease occurring in Newfoundland (Canker or wart disease). Bul. Cent. Exp. Farm, Ottawa, Can., 63: 1-8; 1909.
- 45 JENSEN, J. L. The propagation and prevention of smut in oats and barley. Jour. Roy. Agr. Soc. England, XXIV; part 2: 397-417; 1889.
- 46 KELLERMAN, W. A. Preliminary report on smut in oats. Rept. Kansas Agr. College, 2: 1889.
- 47 KELLERMAN, W. A. and SWINGLE, W. T. Prevention of smut in oats, etc. Buls. Kans. Agr. Coll. 8: 1889; 15: 1890; 22: 1891.
- 48 KELLERMAN, W. A. Prevention of smut in cereals. Agr. Sci. IV: 99; 1890.
- 49 ORTON, W. A. Wart disease of the potato. Cir. Bul. Pl. Ind., U. S. D. A. 52: 1-11; 1910.
- 50 SELBY, A. D. The smut of oats and its prevention. Bul. Ohio Agr. Exp. Sta. 64: 115-139; 1895.
- 51 SELBY, A. D. A rosette disease of potatoes attributed to the sterile fungus *Rhizoctonia*. Bul. Ohio Agr. Expt. Sta. 139: 53-66. 1903. See also Bul. 145: 15-32; 1903.
- 52 SELBY, A. D. and MANN, T. F. Studies in diseases of cereals and grasses. Bul. Ohio Agr. Expt Sta. 203: 187-216; 1909.
- 53 SMITH, E. F. and SWINGLE, D. B. The dry-rot of potatoes due to *Fusarium oxysporum*. Bul. Bur. Pl. Ind. U. S. D. A. 55: 1-64; 1904.
- 54 THAXTER, ROLAND. Potato scab. Rept. Conn. Agr. Exp. Sta. 13: 3-17; 1889. 14: 81-95; 1890.
- 55 VANHOOK, J. M. Blighting of field and garden peas. Bul. Ohio Agr. Expt. Sta. 173: 231-249; 1906.

SOIL INFESTING PARASITES

- See numbers 44, 51, 53, and 54, above.
- Bolley, H. L. See numbers 38, 39, 40, and 41, above.
- 56 GREEN, W. J. Transplanting onions. Bul. Ohio Agr. Expt. Sta. Vol. III, No. 9: 244.
- 57 SELBY, A. D. Investigations of plant diseases in forcinghouse and garden. Bul. Ohio Agr. Expt. Sta. 73: 221-246; 1896.
- 58 SELBY, A. D. The prevention of onion smut. Buls. Ohio Agr. Expt. Sta. 122: 71-84; 1901; also 131: 47-51; 1902.
- 59 STONE, G. A. and SMITH, R. E. The rotting of greenhouse lettuce. Bul. Mass. Agr. Expt. Sta. (Hatch) 69: 1-40; 1900.
- 60 THAXTER, ROLAND. On certain fungus diseases of the onion, *Allium cepa*. Rept. Conn. Agr. Expt. Sta. 13: 129-153; 1889.

SOIL TREATMENT

- 61 RUDD, W. N. Soil steaming. *American Florist* 9: 171; 1893. See also *American Florist* 10: 1038; 1895.
- 62 SELBY, A. D. Soil treatment for the forcinghouse. *Cir. Ohio Agr. Expt. Sta.* 57: 1-7; 1906. See also number 58 above.
- 63 SELBY, A. D. Soil treatment of tobacco plant beds. *Cir. Ohio Agr. Expt. Sta.* 59: 1-4; 1906.
- 64 SELBY, A. D. Seed and soil treatments. *Bul. Ohio Agr. Expt. Sta.* 199: 95-96; 1908.
- 65 SHAMEL, A. D. and COBY, W. W. Methods of steaming tobacco beds. *Bul. Bur. Pl. Ind.* 91: U. S. D. A. 1905.

ROOT DISEASES—ROOT-ROT FUNGI

- 66 BRIGGS, L. J. Field treatment of tobacco root-rot. *Cir. Bur. Pl. Ind. U. S. D. A.* 7: 1-8; 1908.
- 67 GILBERT, W. W. The root-rot of tobacco caused by *Thielavia basicola*. *Bul. Bur. Pl. Ind., U. S. D. A.* 158: 1-55; 1909. Contains Bibliography.
- 68 SELBY, A. D. Root-rot diseases of peach. *Bul. Ohio Agr. Expt. Sta.* 92: 235; 1898.
- 69 SELBY, A. D. Root-rot of tobacco. *Bul. Ohio Agr. Expt. Sta.* 156: 95-97; 1904.
- 70 SMITH, E. F. The root-rot of peach. *Journ. Mycology* 7: 377; 1894.
- 71 THAXTER, ROLAND. Root-rot of violets. *Rept. Conn. Agri. Expt. Sta.* 15: 166-167; 1891.
- 72 WILCOX, E. M. Rhizomorphic root-rot of fruit trees. *Bul. Okla. Agr. Expt. Sta.* 49: 132; 1901.

WOUNDS AND WOUND PARASITES

- FREEMAN, E. M. See number 11.
- 73 SCHRENK, H. VON. The decay of timber and methods of preventing it. *Bul. Bur. Pl. Ind. U. S. D. A.* 14: 1-96; 1902.
- 74 SCHRENK H. VON. A disease of the white ash caused by *Polyporus fraxinophilus*. *Bul. Bur. Pl. Ind., U. S. D. A.* 32: 1-20; 1903.
- 75 SCHRENK, H. VON. Sap-rot and other diseases of the red gum. *Bul. Bur. Pl. Ind. U. S. D. A.* 114: 1-34; 1907.

FUNGICIDES

- 76 CRANDALL, C. S. Bordeaux mixture. *Bul. Ill. Agr. Expt. Sta.* 135: 200-296; 1909. (Contains full references to literature).
- 77 FAIRCHILD, D. G. Bordeaux mixture. *Bul. Div. Veg. Path. and Phys., U. S. D. A.*, 6: 1-55; 1904.
- 78 GREEN, W. J. The spraying of orchards. *Bul. Ohio Agr. Expt. Sta. Vol. IV: No. 9: 193-220; 1891.*
- 79 HEDRICK, U. P. Bordeaux injury. *Bul. N. Y. Agr. Expt. Sta.* 287: 217-286; 1908.
- 80 LODEMAN, E. G. The spraying of plants. 1-110; 1896.
- 81 MILLARDET, A. *Jour. d'Agr. Prat.* October 8, 1885: 513-514.
- 82 PADDOCK, WENDELL. Spray pumps and spraying. *Bul. N. Y. Agr. Expt. Sta.* 121: 196-219; 1897.
- 83 PICKERING, U. Bordeaux mixture (Chemical composition) *Jour. Chem. Soc. London.* Vols. XCI, XCII; 1907: 1988-2001.
- 84 SCOTT, W. M. Self-boiled lime-sulfur as a promising fungicide. *Cir. Bur. Pl. Ind. U. S. D. A.* 1: 1-18; 1908.
- 85 SCOTT, W. M. The substitution of lime-sulfur preparations for Bordeaux mixture in the treatment of apple diseases. *Cir. Bur. Pl. Ind. U. S. D. A.* 54: 1-15; 1910.
- 86 SCOTT, W. M. Lime-sulfur mixtures for the summer spraying of orchards. *Cir. Bur. Pl. Ind. U. S. D. A.* 27: 1-17; 1909.
- 87 SELBY, A. D. Two promising fungicides. *Cir. Ohio Agr. Expt. Sta.* 87: 6-8; 1908.
- 88 SELBY, A. D. and HICKS, J. F. Soda-Bordeaux mixture. *Bul. Ohio Agr. Expt. Sta.* 130: 35-40; 1902.
- 89 SWINGLE, W. T. Bordeaux mixture: Its chemistry, physical properties and toxic effects. *Bul. Div. Veg. Phys. and Path. U. S. D. A.* 9: 1-37; 1896.
- 90 WAITE, M. B. Fungicides and their use in preventing diseases of fruits. *Farmers Bul. U. S. D. A.* 243: 1-32; 1906.

DISEASES OF POME FRUITS

- 91 ALLWOOD, W. B. Ripe-rot or bitter-rot of apples. *Bul. Virginia Agr. Expt. Sta.* 40: 59-82; 1894.
- 92 ARTHUR, J. C. Report of Botanist, *Rept. N. Y. Agr. Expt. Sta.* 3: (1884) 351-385; 1885.
- 93 ARTHUR, J. C. Histology and biology of pear blight. *Proc. Phil. Acad. Nat. Sci.* 1886: 322-341.
- 94 BLAIR, JOS. C. Bitter-rot of apples, Horticultural investigations. *Bul. Ill. Expt. Sta.* 117: 483-551; 1907.
- 95 BURRILL, T. J. Bitter-rot of apples. *Bul. Ill. Expt. Sta.* 77: 351-366; 1902.

- 96 BURRILL, T. J. Bitter-rot of apples. Botanical investigations. Bul. Ill. Expt. Sta. 118: 555-608; 1907.
- 97 BURRILL, T. J. Pear blight. Trans. Ill. State Hort. Soc. 1877: 114; 1878: 80.
- 98 BURRILL, T. J. Pear blight. Proc. Am. Assn. Adv. Sci. 29: 583; 1880.
- 99 CLINTON, GEO. P. Apple rots in Illinois. Bul. Ill. Expt. Sta. 69: 189-224; 1902.
- 100 DETMERS, F. Apple scab. Bul. Ohio Agr. Expt. Sta. Vol. IV, No. 9: 187-192; 1891.
- 101 HALSTED, B. D. The black-rot of the quince. Bul. N. J. Agr. Expt. Sta. 91: 8-10; 1892.
- 102 HASSELBRING, H. Canker of apple trees. Bul. Ill. Expt. Sta. 70: 225-239; 1902.
- 103 LODEMAN, E. G. The sprayings of orchards. Bul. Cornell Agri. Expt. Sta. 86: 47-74; 1895.
- 104 PADDOCK, W. The New York apple tree canker. Bul. N. Y. Agr. Expt. Sta. 163: 179-261; 1899; also 185: 205-213; 1900.
- 105 SCHRENK, H. VON. and SPAULDING, P. The bitter-rot of apples. Bul. Bur. Pl. Ind. U. S. D. A. 44: 1-29; 1903. Contains complete literature list.
- 106 SCOTT, W. M. The control of apple bitter-rot. Bul. Bur. Pl. Ind. U. S. D. A. 93: 1-36; 1906.
- 107 SCOTT, W. M. and ROHRER, J. B. Apple leaf-spot caused by *Sphaeropsis malorum*. Bul. Bur. Pl. Ind. U. S. D. A. 121: 46-54; 1908.
- 108 SELBY, A. D. Bitter-rot, sooty and fly-speck fungus on apple. Bul. Ohio Agr. Expt. Sta. 79: 133-136; 1897.
- 109 SELBY, A. D. Fall and early winter injuries to orchard trees and shrubbery by freezing. Bul. Ohio Agr. Expt. Sta. 192: 129-148; 1908.
- 110 SOUTHWORTH, E. A. Ripe-rot of grapes and apples. Jour. of Mycology, 6: 164-173; 1891.
- 111 STURGIS, W. C. Ripe-rot or bitter-rot. Bul. Conn. Agr. Expt. Sta. 111: 1-5; 1892.
- 112 TAFT, L. R. The ripe-rot or bitter-rot of the apple. (*Gloeosporium fructigenum* Berk.) Bul. Mich. Agr. Expt. Sta. 121: 21, 46-47; 1895.
- 113 WAITE, M. B. Treatment of pear leaf-blight in the orchard. Jour. Mycol., 7: 333-338, 1894.
- 114 WAITE, M. B. Cause and prevention of pear blight. Yearbook U. S. D. A. 1895: 295-300.
- 115 WHETZELL, H. H. The blight canker of apple trees. Bul. Cornell University Expt. Sta. 236: 103-138; 1907.

DISEASES OF STONE FRUITS

- 116 ARTHUR, J. C. Plum-leaf fungus. Rept. N. Y. Agr. Expt. Sta. 8: 293-298; 1889.
- 117 ATKINSON, G. F. Leaf-curl and plum pockets. Bul. Cornell Univ. Agr. Expt. Sta. 73: 319-353.
- 118 BEACH, S. A. Plum leaf-spot; Cherry leaf-spot and fruit-rot. Buls. N. Y. Agr. Expt. Sta. 98: 1-31, 1896; 117: 132-151, 1897.
- 119 DUGGAR, B. M. Peach leaf-curl. Bul. Cornell Agr. Expt. Sta. 164: 371-388; 1899.
- 120 FARLOW, W. G. The black knot. Bul. Bussey Institution, 1876: 440-453.
- 121 HUMPHREY, J. E. The black-knot of the plum. Rept. Mass. Agr. Expt. Sta. 8: 200-210; 1890.
- 122 HUMPHREY, J. E. On *Monilia fructigena*. Bot. Gaz. 18: 85-93; 1893.
- 123 NORTON, J. B. S. Sclerotinia fructigena. Trans. Acad. Sci. of St. Louis, 12: 91-97; 1902.
- 124 PIERCE, N. B. Peach leaf curl: Its nature and treatment. Bul. Div. Veg. Path. and Phys., U. S. D. A. 20: 1-204; 1900.
- 125 SELBY, A. D. Preliminary report upon diseases of the peach. Bul. Ohio Agr. Expt. Sta. 92: 226-231; 1898. See also 104: 201-216, 1899, and 148: 55-68, 1904.
- 126 SELBY, A. D. Variation in the amount of leaf-curl of the peach in the light of weather conditions. Proc. Soc. Prom. Agr. Sci. 20: 98-104; 1899.
- 127 SMITH, ERW. F. Peach blight, *Monilia fructigena* Pers. Jour. Mycol. 5: 123-134, 1889.
- 128 SMITH, ERW. F. Peach yellows: Its cause and control. Bul. Sect. Veg. Path., U. S. D. A. 9: 1-254; 1888. Also Bul. Div. Veg. Path. 1: 58; 1891.
- 129 STEWART, F. C. and EUSTACE, H. J. Shot-hole fungus on cherry fruit pedicles. Rept. N. Y. Agr. Expt. Sta. 20: 146-148; 1901.

DISEASES OF SMALL FRUITS

- 130 DETMERS, FRED. Diseases of the blackberry and raspberry. Bul. Ohio Agr. Expt. Sta. Vol. IV, No. 6: 124-129; 1891.
- 131 DURAND, E. J. A disease of currant canes. Bul. Cornell Univ. Agr. Expt. Sta. 125: 23-38; 1897.
- 132 GALLOWAY, B. T. Experiments made in 1883 in the treatment of the downy mildew and black-rot of the grape-vine. Sect. Veg. Path. U. S. D. A. 10: 1-61; 1889; see also 11: 1-119; 1890.
- 133 PAMMEL, L. H. Spot diseases of currants and gooseberries. Bul. Iowa Agr. Expt. Sta. 13: 67-70; 1891.
- 134 REDDICK, D. The black-rot of the grape and its control. Bul. Cornell Univ. Agr. Expt. Sta. 253: 367-388; 1908.
- 135 SCRIBNER, F. L. Anthracnose of raspberry and blackberry. Rept. U. S. D. A. 1887: 357-367.
- 136 SCRIBNER, F. L. The fungus diseases of the grape-vine. Bul. Div. Bot., U. S. D. A. 2: 28-34; 1886.
- 137 SELBY, A. D. Diseases of currants and gooseberries. Bul. Ohio Agr. Expt. Sta. 73: 102-112; 1897.
- 138 SELBY, A. D. Grape-rots in Ohio. Bul. Ohio Agr. Expt. Sta. 123: 85-94; 1901.

- 139 SELBY, A. D. and HICKS, J. F. Experiments in the prevention of grape-rot. Bul. Ohio Agr. Expt. Sta. **123**: 94-102; 1901.
- 140 SELBY, A. D. and HICKS, J. F. Spraying for grape-rot. Bul. Ohio Agr. Expt. Sta. **130**: 29-51; 1902.
- 141 STEWART, F. C. and EUSTACE, H. J. An epidemic of currant anthracnose. Bul. N. Y. Agr. Expt. Sta. **199**: 63-80; 1901.
- 142 STEWART, F. C. and EUSTACE, H. J. Raspberry cane-blight and raspberry yellows. Bul. N. Y. Agr. Expt. Sta. **226**: 331-364; 1902.

DISEASES OF POTATO, TOBACCO, TOMATO, EGG-PLANT, ETC.

- 143 CLINTON, G. P. Downy mildew or blight, *Phytophthora infestans* (Mont.) DeBy., of potatoes. Rept. Conn. Agr. Expt. Sta. **1904**: 363-384. **1905**: 304-330.
- 144 CLINTON, G. P. Root-rot of tobacco. Rept. Conn. Agr. Expt. Sta. **1906**: 342-368.
- 145 DUGGAR, B. E. and STEWART, F. C. The sterile fungus *Rhizoctonia*. Bul. Cornell Expt. Sta. **186**: 50-76; 1901. Also Bul. N. Y. Agr. Expt. Sta. **186**: 34-30; 1901.
- 146 GILBERT, W. W. The root-rot of tobacco caused by *Thielavia basicola*. Bul. Bur. Pl. Ind., U. S. D. A. **158**: 1-55; 1909. Contains full literature list.
- 147 HALSTED, B. D. Some fungous diseases of the egg-plant. Rept. N. J. Agr. Expt. Sta. **12**: 277-279; 1891.
- 148 JONES, L. R. Certain potato diseases and their remedies. Bul. Vt. Agr. Expt. Sta. **72**: 13-16; 1899.
- 149 JONES, L. R. Diseases resistance of potatoes. Bul. Bur. Pl. Ind. U. S. D. A. **87**: 1-39; 1905.
- 150 ORTON, W. A. Potato failures in San Joaquin Valley, California. Cir. Bur. Pl. Ind. U. S. D. A. **23**: 1-14; 1909.
- 151 ROLFS, F. M. Potato failures. Bul. Colo. Agr. Expt. Sta. **70**: 1-20; 1902. Also **91**: 1-33; 1904.
- 152 ROLFS, P. H. Tomato diseases. Bul. Fla. Agr. Expt. Sta. **91**: 15-34; 1907.
- 153 SELBY, A. D. On the occurrence of *Phytophthora infestans* and *Plasmopara cubensis* in Ohio. Ohio Naturalist, **7**: 79-85; 1907. See also No. 51.
- 154 SELBY, A. D. Tobacco diseases in Ohio. Bul. Ohio Agr. Expt. Sta. **156**: 87-107; 1904.
- 155 SELBY, A. D. Tomato diseases. Bul. Ohio Agr. Expt. Sta. **73**: 237-245; 1896. Also **105**: 232-234; 1899. See also No. 13.
- 156 SMITH, E. F. A bacterial disease of the tomato, egg-plant and Irish potato. Bul. Div. Veg. Path. and Phys., U. S. D. A. **12**: 1-26; 1896.
- 157 SMITH, E. F. The Granville tobacco wilt. Bul. Bur. Pl. Ind., U. S. D. A. **141**: 17-24; 1908.
- 158 SMITH, E. F. and SWINGLE, D. B. The dry-rot of potatoes due to *Fusarium Oxysporum*. Bul. Bur. Pl. Ind., U. S. D. A. **55**: 1-64; 1904.
- 159 STEVENS, F. L. and SACKETT, W. G. The Granville tobacco wilt. Bul. N. C. Agr. Expt. Sta. **188**: 1903.
- 160 STEWART, F. C. Potato diseases on Long Island in the season of 1895. Bul. N. Y. Agr. Expt. Sta. **101**: 72-86; 1896.
- 161 STEWART, F. C. Spraying potatoes on Long Island in the season of 1896. Bul. N. Y. Agr. Expt. Sta. **123**: 234-259; 1897.
- 162 STEWART, F. C., EUSTACE, H. J. and SIKKINE, F. A. Potato spraying experiments in 1906. Bul. N. Y. Agric. Expt. Sta. **279**: 154-229. The same **296**: 307-311.

DISEASES OF VEGETABLE AND FIELD CROPS (EXCEPT SOLANACEOUS PLANTS)

- 163 ARTHUR, J. C. Lettuce mildew. Rept. N. Y. Agr. Expt. Sta. **4**: 253-254; 1885.
- 164 BEACH, S. A. Bean anthracnose and its treatment. Rept. N. Y. Agr. Expt. Sta. **11**: 531-552; 1892.
- 165 FULTON, H. R. Bean diseases. Bul. La. Expt. Sta. **101**: 9-13; 1908.
- 166 GALLOWAY, B. T. A record of some of the work of the division. Bul. Div. of Bot. U. S. D. A. (Sec. of Veg. Path.) **8**: Part II: 41-67; 1889.
- 167 HALSTED, B. D. The asparagus rust; its treatment and natural enemies. Bul. N. J. Agr. Expt. Sta. **129**: 1-20; 1898.
- 168 HALSTED, B. D. Laboratory study of fruit decays. Rept. N. J. Agr. Sta. **13**: 326-333; 1892.
- 169 HALSTED, B. D. Club-root of cabbage and its allies. Bul. N. J. Agr. Expt. Sta. **98**: 1-16; 1893.
- 170 HALSTED, B. D. Some fungous diseases of the sweet potato. Bul. N. J. Agr. Expt. Sta. **76**: 1-32; 1890.
- 171 HALSTED, B. D. and FAIRCHILD, D. G. Sweet potato black-rot. Jour. Myc. **7**: 1-11; 1891.
- 172 HUMPHREY, J. Z. The cucumber mildew. Rept. Mass. Agr. Expt. Sta. **8**: 210-212; 1890.
- 173 PAMMEL, L. H. Preliminary notes on root-rot disease of sugar beets. Bul. Iowa Agr. Expt. Sta. **243**: 243-251; 1891.

- 174 PAMMEL, L. H. Bacteriosis of ruta-baga. Bul. Iowa Agr. Expt. Sta. **27**: 130-135; 1895.
 175 RUSSELL, H. L. Bacterial rot of cabbage and allied plants. Bul. Wis. Agr. Expt. Sta. **65**: 1-39; 1898.
 176 SCRIBNER, F. L. Anthracnose of the bean. Rept. Sec. Veg. Path., U. S. D. A., **1887**: 361-364.
 177 SELBY, A. D. Diseases of cucurbits. Bul. Ohio Agr. Expt. Sta. **89**; 1897 and **105**; 1899.
 178 SELBY, A. D. Additional host plants of *Plasmopara cubensis*. Bot. Gaz. XXVII: 67-68; 1899.
 179 SELBY, A. D. Lettuce leaf perforation and other lettuce diseases. Bul. Ohio Agr. Expt. Sta. **73**: 222-226; 1896.
 180 SELBY, A. D. A rosette disease of lettuce. Cir. Ohio Agr. Expt. Sta. **57**: 1-7; 1906.
 181 SELBY, A. D. Onion smut and its prevention. Buls. Ohio Agr. Expt. Sta. **122**: 71-84; 1900, **131**: 47-52; 1902.
 182 SMITH, ERW. F. The black-rot of cabbage. Farmers' Bul. U. S. D. A. **68**: 1-21; 1898. See also Centrbl. f. Bakt. Parask. u. Infektkr. **3**: (II. Abt.) 1897.
 183 SMITH, R. E. Botrytis and Sclerotinia: Their relation to certain plant diseases and to each other. Bot. Gaz. XXIX: 389-407; 1900.
 184 STEWART, F. C. Downy mildew of the cucumber: What it is and how to prevent it. Bul. N. Y. Agr. Expt. Sta. **119**: 154-183; 1897.
 185 STONE, G. E. and SMITH, R. E. "Drop" of lettuce. Rept. Mass. Agr. Expt. Sta. **9**: 79-81; 1897.
 186 STURGIS, W. C. The mildew of lima beans. Rept. Conn. Agri. Expt. Sta. **1897**: 159-166. Also Bot. Gaz. XXV: 191-194; 1898.
 187 THAXTER, R. Mildew of lima beans. Rept. Conn. Agr. Expt. Sta. **13**: 167-171; 1889.
 188 THAXTER, R. Diseases of the onion. Rept. Conn. Agri. Expt. Sta. **13**: 129-166; 1889.
 VANHOOK, J. M. See No. 55.
 189 WHETZEL, H. H. Some diseases of beans. Bul. Cornell Agr. Expt. Sta. **239**: 198-214, 1906.

DISEASES OF CEREALS AND GRASSES

- 190 ARTHUR, J. C. The rusts (Uredineales). North Am. Flora **7**: 83-160; et seq.
 191 MANNS, T. F. The blade blight of oats; a bacterial disease. Bul. Ohio Agr. Expt. Sta. **210**: 91-167; 1909.
 192 SELBY, A. D. Some diseases of wheat and oats. Bul. Ohio Agr. Expt. Sta. **97**: 31-61, 1898.
 193 SELBY, A. D. and MANNS, T. F. Studies in diseases of cereals and grasses. Bul. Ohio Agr. Expt. Sta. **203**: 187-236; 1909.
 194 STEWART, F. C. A bacterial disease of sweet corn. Bul. N. Y. Agr. Expt. Sta. **130**: 423-439; 1897.

DISEASES OF FORAGE CROPS

- 195 BAIN, S. M. and ESSARY, S. H. A new anthracnose of alfalfa and red clover. Jour. Myc. **12**: 192-193; 1908.
 196 BAIN, S. M. and ESSARY, S. H. Selection for disease-resistant clover. Bul. Tenn. Agr. Expt. Sta. **75**: 1-10; 1906.
 197 CHESTER, F. D. Clover diseases. Rept. Del. Agr. Expt. Sta. **3**: 79-88; 1890.
 198 COMBS, ROBT. The alfalfa leaf-spot disease. Bul. Iowa Agr. Expt. Sta. **36**: 858-859; 1897.
 199 PAMMEL, L. H. Clover rust. Bul. Iowa Agr. Expt. Sta. **13**: 51-55; 1891.
 200 SACKETT, W. G. A bacterial disease of alfalfa. Bul. Colo. Agr. Expt. Sta. **158**: 1-32; 1910.
 201 SELBY, A. D. and MANNS, T. F. Studies in diseases of cereals and grasses. Bul. Ohio Agr. Expt. Sta. **203**: 187-236; 1909.

DISEASES OF FOREST AND SHADE TREES

- 202 ATKINSON, GEO. F. Studies of some shade tree and timber destroying fungi. Bul. Cornell Agr. Expt. Sta. **193**: 199-235; 1901.
 203 EDGERTON, C. W. The physiology and development of some anthracnoses, including one on sycamore. Bot. Gaz. **45**: 367-408; 1908.
 204 KLEBAHN, H. Unters. über einige Fungi imperfecti u.d. zugehörigen Ascomycetenformen. Jahrb. f. wiss. Bot. **41**: 515-558; 1905.
 205 METCALF, HAVEN. Diseases of ornamental trees. Yearbook, U. S. D. A. **1907**: 483-494.
 206 SCHRENK, H. VON. Two diseases of red cedar. Bul. Div. Veg. Phys. and Path. U. S. D. A. **21**: 1-22; 1900.
 207 SCHRENK, H. VON. Some diseases of New England conifers. Bul. Div. Veg. Phys. and Path. U. S. D. A. **25**: 1-56; 1900.

- 208 SCHRENK, H. VON. Fungus diseases of forest trees. Yearbook U. S. D. A. 1900: 199-210.
- 209 SCHRENK, H. VON. A disease of the white ash caused by *Polyporus fraxinopholus*. Bul. Bur. Pl. Ind. U. S. D. A. 32: 1-18; 1903.
- 210 SCHRENK, H. von. A disease of the black locust (*Robinia pseudacacia* L.). Rept. Missouri Bot. Garden 12: 21-31; 1901.
- 211 SCHRENK, H. VON. and SPAULDING, P. Diseases of deciduous forest trees. Bul. Bur. Pl. Ind. U. S. D. A. 149: 1-85; 1909. (Contains complete literature list).
- 212 SPAULDING, PERLEY. The treatment of damping off in coniferous seedlings. Cir. Bur. Pl. Ind. 4: 1-8; 1908.
- 213 SCRIBNER, F. L. A disease of sycamore. Rept. U. S. D. A. 1888: 387-389.
- 214 SOUTHWORTH, E. A. *Gloeosporium nervisequum* (Fekl.) Sacc. on sycamore. Jour. Myc. 5: 51-52; 1889.
- 215 WOODS, A. F. and GALLOWAY, B. T. Diseases of shade and ornamental trees. Yearbook, U. S. D. A. 1896: 237-254.

DISEASES OF ORNAMENTAL PLANTS

- 216 ARTHUR, J. C. Chrysanthemum rust. Bul. Ind. Agr. Expt. Sta. 85: 145-150; 1900.
- 217 ATKINSON, G. F. A new anthracnose of privet. Bul. Cornell Agr. Expt. Sta. 49: 306-314; 1892.
- 218 DUDLEY, W. R. The hollyhock rust. Bul. Cornell Agr. Expt. Sta. 25: 154-155; 1890.
- 219 HALSTED, B. D. Repts. N. J. Agr. Expt. Sta. 11; 1890; 12: 1891; 13: 1892; 14: 1893. Gives descriptions of diseases of many ornamental plants.
- 220 HEALD, F. D. The bud rot of carnations. Bul. Neb. Agr. Expt. Sta. 103: 1-8; 1908.
- 221 MURRILL, W. A. A serious chestnut disease (bark disease). Jour. N. Y. Bot. Gaz. 7: 143-153; 1906. Also 7: 203-211; 1906.
- 222 SMITH, E. F. Wakker's hyacinth germ. Bul. Div. Veg. Phys. and Path. U. S. D. A. 26: 1-45; 1901. Also Bul. 23: 1-153; 1901.
- 223 STEWART, F. C. Combating carnation rust. Bul. N. Y. Agr. Expt. Sta. 100: 32-68; 1896.
- 224 STEWART, F. C. An anthracnose and a stem rot of cultivated snap-dragon. Bul. N. Y. Agr. Expt. Sta. 179: 105-110; 1900.
- 225 STEWART, F. C. and HODGKISS, H. E. The bud rot of carnations and the silver top of June grass. Tech. Bul. N. Y. Agr. Expt. Sta. 7: 83-119; 1908.
- 226 TOWNSEND, C. O. A soft rot of the calla lily. Bul. Bur. Pl. Ind. U. S. D. A. 60: 1-44; 1904.

PREFACE.

That portion of this bulletin which has to do with plant substances marks the first step in a program of investigation of the phosphorus compounds of the food of animals.

This study is necessary as a preliminary to the practical application of the results of our animal metabolism experiments with pure phosphorus compounds.

The greatest difficulty in the way of a quantitative estimation of the groups of phosphorus compounds in vegetable substances has been the accurate separation of inorganic phosphates from the salts of phytic acid.

The solution of this problem opens up an important field to a new and promising line of attack, and points the way with considerable certainty to the estimation of phytin and nuclein phosphorus.

The solution of the problem of estimation of inorganic phosphorus in a wide range of animal tissues makes judgment possible as to the availability of the phosphorus of the food for the nutrition of the functional substance of these parts.

BULLETIN

OF THE

Ohio Agricultural Experiment Station

NUMBER 215.

APRIL, 1910

METHODS FOR THE QUANTITATIVE ESTIMATION OF INORGANIC PHOSPHORUS IN VEGETABLE AND ANIMAL SUBSTANCES.

BY E. B. FORBES, A. LEHMANN, R. C. COLLISON AND A. C. WHITTIER.

INTRODUCTION.

In studying the nutritive value of vegetable foods, either in their usual state, or as modified by the chemical constitution of soils or fertilizers, it is important that we distinguish between organic and inorganic phosphorus, and in considering the specific effects of nutrients on the development of animals and the composition of their organs and tissues, it is a matter of great interest and importance that we know whether or not variations in their phosphorus content involve the simple inorganic salts in solution in their liquids, or the complex organic phosphorus compounds of the living structures.

This distinction is of significance in animal nutrition especially, because of the limited usefulness as nutrients of mineral elements in an inorganic condition.

We have no reason to expect that variations in the food will produce especially marked variations in the inorganic phosphorus content of animal tissues. In order, therefore, to get the results desired, it is necessary that the method used for the estimation of inorganic phosphorus be as nearly as possible chemically and mechanically perfect.

On these accounts, and as a part of the general program of study of the nutritive value of compounds of phosphorus, which is in progress in this department, we have undertaken a solution of the problem of quantitative estimation of inorganic phosphorus in plant and animal substances generally.

A number of methods for these determinations have been published but have been found to be either inaccurate or cumbersome, and therefore we have given the subject some attention.

Conclusions have been reached which give us convenient and approximately accurate methods for the estimation of inorganic phosphorus in a wide range of plant and animal substances.

As a problem in quantitative chemical analysis the estimation of inorganic phosphorus in vegetable substances is rendered particularly difficult by the facts that in each substance under observation we have a different mixture of phosphates, variously related, both chemically and physically, to different groups of organic compounds.

The problem of complete extraction may be influenced by the mechanical relation of the phosphates to insoluble and impenetrable structures, and the possibility of hydrolysis of organic phosphorus compounds by the extractive reagents introduces into the problem an element of uncertainty for the removal of which our present knowledge of the relations of phosphorus to organic compounds in plants does not begin to suffice.

Further, combinations of inorganic phosphorus with organic compounds, such as may occur without the agency of a vital process in a living organism, introduce an element of embarrassment into the discussion, as also does the fact that there is no clear-cut and essential distinction between organic and inorganic compounds generally, but these several objections to the general idea of such a separation as we contemplate do not have weight sufficient to prevent the solution of the problem on a useful working basis.

ESTIMATION OF INORGANIC PHOSPHORUS IN VEGETABLE SUBSTANCES.

Of the various methods which have come to the attention of the authors, that used by Hart and Andrews* appeared to give the most specific starting-point for further work. The essential points of this method are as follows:

1. Extract 5 grams of sample by shaking for 15 minutes in 125 c. c. of .2 percent hydrochloric acid.
2. Filter, and wash with water until filtrate measures 500 c. c.
3. Neutralize a 200 c. c. portion of this filtrate with ammonia. Precipitate at 65° with 10 grams of ammonium nitrate, 25 c. c. of neutral ammonium molybdate solution and 2 c. c. of nitric acid, specific gravity 1.20. Keep at this temperature for 15 minutes; allow to cool gradually, and filter after one hour.
4. Treat this precipitate as is usual in a phosphorus estimation, dissolving in ammonia, precipitating with magnesia mixture, burning to the pyrophosphate, and then redissolving and reprecipitating to free from impurities.

*Bul. 238, New York Agr. Exp. Sta., p. 188.

Hart and Andrews found that the official molybdate solution decomposed nucleinic acid.¹

In order to reduce this decomposition to a minimum they used neutral ammonium molybdate solution with just sufficient nitric acid to precipitate the phosphoric acid present. This quantity they state to be 2 c. c. of 1.20 nitric acid.²

The second precipitation as magnesium ammonium phosphate was advised by them to remove from the pyrophosphate possible contamination from magnesium oxide resulting from proteid-magnesium compounds precipitated along with the magnesium ammonium phosphate by the magnesia mixture.³

In making use of this method we found it not entirely satisfactory, and on the following accounts:

1. The time allowed for extraction appears to be insufficient.
2. The precipitation with neutral molybdate solution and the minimum amount of acid, is rendered difficult, as a routine method, by the fact that 2 c. c. of 1.20 nitric acid are in many cases not nearly sufficient to cause precipitation of the inorganic phosphorus.

3. The bulky, flocculent precipitate which is often formed may completely mask the formation of the yellow precipitate of inorganic phosphorus, rendering it impossible to judge of the completeness of the precipitation.

4. The precipitate is, with many products, very difficult to filter.

5. This method involves the precipitation of inorganic phosphorus in the presence of phytin. A quantitative precipitation of inorganic phosphorus alone, from a solution containing phytin, appears to be impossible.

6. Nucleinic acid may be hydrolized by the nitric acid used in this precipitation, the result being the formation of inorganic from organic phosphorus.

7. Nucleinic acid, like phytin, appears to hinder the formation of the yellow precipitate.

8. A possible source of error lies in the carrying down of phosphorus-containing proteids with the yellow precipitate, the solution of these proteids in ammonia, their precipitation with magnesia mixture, and in this way their contribution to the amount of the pyrophosphate.

In an attempt to remedy the imperfections of this method we made the following observations:

¹Bul. 238, New York Agr. Exp. Sta., p. 188.

²Bul. 238, New York Agr. Exp. Sta., p. 189.

³Bul. 238, New York Agr. Exp. Sta., p. 191.

The time of extraction in .2 percent hydrochloric acid may be safely lengthened, at least for most substances, to three hours.*

The decomposition of nucleinic acid by the nitric acid used in the molybdate precipitation, is obviated by substituting for this first process, a precipitation with magnesia mixture, since free nucleinic acids and some at least of their salts are soluble in ammonium hydrate.

Besides getting rid of the nucleinic acids, this precipitation largely removes the mechanical difficulty of handling the bulky, flocculent, molybdate precipitate, and obviates the necessity for the delicate determination for each substance studied, of the point of compromise between completeness of precipitation of inorganic phosphates and decomposition of organic phosphorus compounds by nitric acid.

The precipitate with magnesia mixture is very much less bulky, and is more easily filterable, and in this case there is no doubt as to the completeness of the process.

The interference of phytin with the estimation of inorganic phosphorus, which may amount to a complete suppression of the yellow precipitate if this compound be present in considerable amount, or which may, through decomposition, add to the inorganic phosphorus if the phytin be present in smaller quantity, is entirely done away with by the separation of phytin and inorganic phosphorus in the precipitate with magnesia mixture, by dissolving the inorganic phosphates out of this precipitate with acid-alcohol. The phytin is practically, if not entirely insoluble in this reagent.

Below are details of work sustaining these conclusions.

The problem of removal of nucleinic acids from the .2 percent hydrochloric acid extract was worked out by experiments with a preparation of nucleinic acid from yeast. The free nucleinic acid and some of its salts, at least the magnesium compound, proved soluble in ammonium hydrate. This fact led to the separation of inorganic from nucleinic acid phosphorus by precipitating with magnesia mixture and filtering out the precipitate.

The preliminary precipitation with magnesia mixture has the double advantage of removing the nucleinic acid and of facilitating subsequent work. After dissolving the magnesia precipitate in hydrochloric acid, the molybdate solution produces a normal yellow precipitate which is free from the bulky flocculent mass which frequently entirely obscures, if indeed it does not prevent, the

*The use of phenol in the extractive reagent would probably prevent the activity of enzymes in substances where they are particularly active, though unless proven necessary the use of phenol is inadvisable.

formation of the yellow precipitate when the hydrochloric acid extract of the substance is treated directly with the molybdate solution.

After working out this point we learned from correspondence with Parke, Davis & Co., of Detroit that this magnesia precipitation was in use by this firm in the estimation of inorganic phosphorus in their preparation of nucleinic acid from yeast.

In order to determine whether or not nucleinic acid was decomposed in ammonia solution during our first magnesia precipitation, we weighed out three 1-gram portions of nucleinic acid which had been prepared from yeast. These were dissolved in ammonia, and allowed to stand over night with magnesia mixture, as in the first step of our method for inorganic phosphorus estimation. Slight precipitates formed, which we combined, dissolved and reprecipitated, first with molybdate solution and then with magnesia mixture, but the combined precipitates were unweighable.

That conditions were correct for precipitation of inorganic phosphorus, was proven by addition of sodium phosphate to another sample of nucleinic acid, which was dissolved and treated like the three above mentioned. The phosphorus came down promptly in the usual way.

U. Suzuki and others* have found that in certain foods and fodders which they examined, including wheat bran and barley, a large portion of the organic phosphorus is present as phytin, and that accompanying this is an enzyme which decomposes phytin into phosphoric acid and inosite.

Attempts were made to prevent possible decomposition by enzymes during the estimation of inorganic phosphorus, by previous heating of the material, both by dry heat and by boiling, but the results were unfavorable to the use of this principle in a routine quantitative method.

After demonstrating that a longer time of extraction than 15 minutes was desirable, we sought to learn whether or not the action of enzymes might be expected to enter largely into the determination of results with the longer extraction.

Inorganic phosphorus was determined in two samples of wheat middlings by two different methods of procedure.

The extractions were made with .2 percent hydrochloric acid, and the extracts allowed to stand over night, two with 6.6 percent of phenol in the extractive reagent, and the other two in the .2 percent hydrochloric acid alone. The extracts were allowed to stand over night in order to give the enzymes a fair chance to demonstrate their presence.

*Bul. No. 4, Vol. 7, College of Agriculture, Tokio.

One sample gave us .006 percent of inorganic phosphorus with phenol present and .010 percent without. The other sample gave .005 percent and .012 percent with and without phenol.

While the amounts of inorganic phosphorus involved were very small the variations in the percent of inorganic phosphorus were considerable, and on the strength of this evidence we began the use of phenol in our provisional method, without having demonstrated that enzymes would make an appreciable difference in the inorganic phosphorus during our three-hour extraction, and without having determined that there was no bacterial growth in our .2 percent hydrochloric acid extract during the twenty-four hours which it stood.

These above results are comparative only, since they were obtained by precipitation in the presence of phytin.

After some preliminary work with the method of Hart and Andrews, certain modifications were compared with the original method. The results are set forth in the following table.

COMPARISON OF MODIFICATIONS OF HART AND ANDREWS'S METHOD
Percent of Inorganic Phosphorus

		Method 1	Method 2	Method 3	Method 4
		Hart's method, 15 minutes extraction; 2 c. c. nitric acid used in precipitation	Hart's method as in Column 1, but with 3 hrs. extraction; 2 c. c. nitric acid used in precipitation	Hart's method as in Column 1, but with 3 hrs. extraction, and 7 c. c. nitric acid used in precipitation	Modified by use of phenol in extractive reagent, and preliminary magnesium precipitation; phosphorus then precipitated by official molybdic solution
1	Gluten flour.....	.035	.053	.053	.044
2	Gluten feed.....	.082	.119	.171	.149
3	Cotton seed meal..	.044	.105	.140	.118
4	Distiller's grains..	.039	.055	.082	.067
5	Corn stover.....	.028	.061	.086	.078
6	Bermuda grass.....	.020	.131	.179	.174
7	Alfalfa hay.....	.028	.097	.145	.140
8	Clover hay.....	.....	.073	.103	.091

With the Hart and Andrews method as in Columns 1, 2, and 3, the preliminary precipitation was with neutral molybdate solution and varying amounts of nitric acid.

It will be observed that the figures in the second column are all higher than the corresponding figures in the first column, showing that 15 minutes extraction is insufficient.

There is, of course, a possibility that the greater amount of inorganic phosphorus found by the three-hour extraction, than by the fifteen-minute extraction, is due to hydrolytic decomposition of organic phosphorus compounds by the .2 percent hydrochloric acid during extraction, rather than to greater thoroughness of extraction.

In order to test this point we determined the inorganic phosphorus in phytin and in nucleinic acid, in one set of samples precipitating immediately after solution, in another set after 3 hours' standing, and in a third after 24 hours' standing in the .2 percent hydrochloric acid. We were unable to demonstrate decomposition in this reagent in either 3 or 24 hours' extraction.

The figures in the third column are, with one exception, higher than the figures in the second, which may be due either to the 2 c. c. of nitric acid used in Method 2 being insufficient to cause complete precipitation, or to the 7 c. c. of acid used in Method 3 being excessive, and augmenting the amount of inorganic phosphorus by decomposition of organic forms, or both decomposition and incomplete precipitation may have affected results.

After precipitation of inorganic phosphorus as with Method 2 with 2 c. c. of nitric acid, 5 c. c. of nitric acid were added to the filtrates to test the thoroughness of the precipitation. The characteristic yellow precipitate promptly appeared in all cases, except with gluten flour.

The figures with Method 4 are, with one exception, higher than the corresponding figures with Method 2, showing that the 2 c. c. of nitric acid used with Method 2 were insufficient. These figures are with one exception, lower than the corresponding figures with Method 3, showing that either the use of phenol in the extractive reagent, or the elimination by the magnesia precipitation of the possibility of decomposition of nucleinic acid by nitric acid, or both, tended to obviate probable inaccuracies in this method of work.

Subsequent investigation, however, showed that Method 4 was unreliable, because of the presence of phytin in the solution from which the inorganic phosphorus was precipitated; so the determinations have a comparative but not an absolute value.

In order to study the bearing of fineness of grinding of the sample on this method of work, a coarsely ground sample of blue-grass was divided into two equal parts and one of these was re-ground. Both samples were then passed through standard sieves with the following results:

PERCENT OF MATERIALS RETAINED BY SEIVES

	2 mm.	1 mm.	.5 mm.	Pan
Coarsely ground.....	0	44	33	23
Finely ground.....	0	0	7	93

Method 4 gave .106 percent of inorganic phosphorus in the finely ground sample and .109 percent in the coarsely ground sample, indicating that extreme fineness of division of such fodders as

blue-grass is probably not essential, and that our failure to extract all of the inorganic phosphorus in 15 minutes was in all probability not due to insufficient fineness of division of the material.

The method of extraction and precipitation used throughout the greater part of this study is as follows:

Place 25 c. c. of 90 percent phenol in a flask graduated to deliver 500 c. c.; add a small portion of .2 percent hydrochloric acid, and shake the flask until the phenol is dissolved. Then fill to the mark with .2 percent hydrochloric acid, and pour the contents upon 10 grams of the sample in a 600 c. c. Florence flask. Close the flask with a rubber stopper and shake at intervals of 5 minutes for three hours.

At the end of this period filter the extract through a dry paper. To a 350 c. c. portion of the filtrate add 10 c. c. of magnesia mixture and 50 c. c. of strong ammonia, and allow to stand over night.

Inorganic phosphorus is precipitated as magnesium ammonium phosphate, along with phytin if present, while nucleins, being soluble in ammonia, remain in solution. Next morning filter, and wash the precipitate free from phenol with dilute ammonia.

In the case of materials containing phytin, such as wheat bran and middlings, the precipitate consists almost wholly of phytin and magnesium ammonium phosphate. It is dark gray in color, and usually completely soluble in dilute acids. In the case of materials containing no phytin, it consists of impure magnesium ammonium phosphate, usually contaminated with variously colored unknown compounds.

Determination of inorganic phosphorus in this precipitate by dissolving in dilute acid, and precipitation with molybdate solution, did not give true results in the presence of phytin.

Experiments were now made on the action of phytin on the precipitation of inorganic phosphorus. In this work a commercial preparation of phytin was used. This material was a calcium-magnesium salt prepared by the Society of Chemical Industry, in Basle, Switzerland. It contained 19.9 percent of phosphorus. The sample was probably contaminated by a small quantity of inorganic phosphorus, since a separation from the latter is very difficult.

Definite quantities of this phytin were dissolved in 0.2 percent hydrochloric acid; a definite quantity of inorganic phosphorus in the form of di-sodium phosphate was added, and the solution precipitated with official molybdate solution in the usual way.

The following series of figures gives the results of the first trial:

The phytin in each case was dissolved in 100 c. c. of 0.2 percent hydrochloric acid, to which was added di-sodium phosphate, equivalent to 0.0420 gram of magnesium pyrophosphate. Ammonium nitrate and 40 c. c. of official molybdate solution were used in the precipitation of the inorganic phosphorus. The number of grams of phytin in each case represents approximately the percent of phytin in the solution.

SUPPRESSION OF YELLOW PRECIPITATE BY PRESENCE OF PHYTIN

Grams of phytin	Grams of pyrophosphate equivalent to inorganic phosphorus added	Grams of pyrophosphate recovered
1.0	.0420	.0000
0.5	"	.0260
0.4	"	.0329
0.3	"	.0371
0.2	"	.0423
0.1	"	.0447
0.05	"	.0438
0.03	"	.0433
0.01	"	.0422
0.00	"	.0420

The striking fact about this series is that a one-percent solution of phytin completely suppressed the precipitation of the inorganic phosphorus present, there being no yellow precipitate after an hour's digestion at 65° C. This suppression of the yellow precipitate seemed to diminish with decrease in the phytin content of the solution, as shown by the increase in the weights of pyrophosphate as the corresponding amounts of phytin were decreased from 1 gram to .2 of a gram. With continued decrease in the phytin present, however, the results increased to quantities in excess of the blank. This may have been due to a decreased suppression of the precipitate by the lower percentages of phytin, the phosphorus in excess of the blank being contributed by the inorganic phosphorus present as an impurity in the phytin; or with decrease in the amount of phytin present, there may have been an increased splitting off of inorganic phosphorus from phytin.

The result on a .2 percent solution of phytin may have been due to a combination of two compensating errors, one the partial hydrolysis of phytin, and the other the partial suppression of precipitation by the presence of phytin, the combination of these factors resulting in a check with the blank.

Later results indicate that the high results with the low percents of phytin were partly due to the formation of inorganic phosphorus by the decomposition of phytin.

The results would naturally be higher than the blank because of the presence of appreciable quantities of inorganic phosphorus in the phytin sample, but this would not account for the low results obtained when considerable phytin is present, nor for the high results later obtained on low-phytin solutions. Duplicate series of determinations were made, all of which gave similar indications.

When using neutral molybdate, although decomposition was not so marked, as indicated by high results on low-phytin solutions, it was necessary in many cases to add more than the 2 c. c. of nitric acid, as specified by Hart and Andrews, in order to effect a separation of the yellow precipitate, while in 0.5 percent and 1.0 percent solutions of phytin, the yellow precipitate was completely suppressed as before.

It was also observed at this time that when the di-sodium phosphate solution was added to the 0.2 percent hydrochloric acid solution of phytin, a cloudiness was at first produced, which disappeared on stirring. In a one-percent solution of phytin it was found possible actually to precipitate the phytin with a strong solution of di-sodium phosphate, indicating either a partial salting out of the phytin, or a combination of inorganic phosphate with the phytin, due to a possible unsaturated condition of the latter.

Considering the results obtained thus far, it was obvious that a separation of phytin from inorganic phosphorus was necessary, if exact results were to be secured.

A quantitative separation of inorganic phosphorus from such a substance as phytin, is a task attended by considerable difficulty, because of the similarities in solubility and the difficulty of preventing hydrolysis of the phytin.

No organic liquid was found in which phytin is appreciably soluble. The only solvent seemed to be dilute acids, in which, of course, inorganic phosphates are also soluble. Phytin is precipitated from such solutions by alkalis and strong alcohol. Inorganic phosphates precipitate under the same conditions, when bases such as calcium and magnesium are present, as in the case of acid extracts of feeding materials.

Owing to the very limited number of solvents for phytin, methods of precipitation in acid solution were investigated.

It was found that aluminium salts cause a precipitation of phytin in a 0.2 percent hydrochloric acid solution of the latter. By adding ammonium nitrate and digesting at 60° C. we were able to precipitate the phytin from even a .01 percent solution of the same.

A number of series of determinations were made, using potash alum as the precipitant. The phytin was in each case dissolved in 100 c. c. of 0.2 percent hydrochloric acid in a 250 c. c. flask. Inorganic phosphorus was added as usual, and also 30 grams of solid ammonium nitrate. The flask was filled nearly to the mark with 0.2 percent acid, and then the phytin precipitated with a small excess of a saturated solution of alum. The flask was then filled to the mark, shaken, and the contents digested at 60° C. for one hour. The contents were then filtered through dry papers, and a measured portion was taken for determination of inorganic phosphorus. Under these conditions phytin was precipitated even in 0.01 percent solutions, but came down as an exceedingly soft, bulky and finely divided precipitate, which could not be held satisfactorily by any kind of filter. A series made by this method gave the following results:

SEPARATION OF INORGANIC PHOSPHORUS AND PHYTIN BY
PRECIPITATION WITH POTASH ALUM

Grams of phytin present	Grams of pyrophosphate equivalent to inorganic phosphorus added	Grams of pyrophosphate recovered
0.5	.0672	.0621
0.4	.0672	.0654
0.3	.0672	.0656
0.2	.0672	.0657
0.1	.0672	.0664
0.05	.0672	.0645
0.04	.0672	.0644
0.03	.0672	.0650
0.02	.0672	.0650
0.01	.0672	.0652

At the same time, samples of the phytin used were treated in a similar way, without the addition of inorganic phosphate. They gave the following results:

Grams of phytin present	Grams of pyrophosphate recovered
0.5	.0117
0.3	.0095
0.1	.0033
0.05	.0009

Now if these latter values are assumed to represent the amount of inorganic phosphorus in the phytin sample, they should be added to the .0672 gram present in inorganic form in order to obtain the true values for inorganic phosphorus; for example, in the case of a 0.5 percent solution of phytin, .0672 gram of pyrophosphate should have been recovered, plus what the phytin itself contained, namely .0117 gram. Therefore, $.0672 + .0117 = .0789$ gram magnesium pyrophosphate, which presumably represents the correct value for inorganic phosphorus in the 0.5 percent solution.

When the series is thus worked out it is readily seen that the results are all too low.

Thinking that possibly the low results were due to a dragging down of inorganic phosphorus by the bulky precipitate of phytin, we made several series of determinations in which the precipitate was thoroughly washed with warm 0.2 percent hydrochloric acid, but in all cases the precipitate, being so finely divided, was washed through into the filtrate. It could not be held by filter paper, paper pulp or asbestos.

We next tried precipitating the phytin as the lead salt in 0.2 percent nitric acid solution. The details of the method were similar to those of the alum method, except that no ammonium nitrate was used in the digestion of the precipitated lead salt.

By the use of a 20 percent solution of lead nitrate, complete precipitation of the phytin seemed to be obtained. The precipitate was heavier and more easily filtered than the aluminium salt.

Experiments proved that 0.2 percent nitric acid was the best medium in which to make the precipitation.

This method gave results indicated by the following series:

SEPARATION OF INORGANIC PHOSPHORUS AND PHYTIN BY
PRECIPITATION WITH LEAD NITRATE

Grams of phytin present	Grams of pyrophosphate equivalent to inorganic phosphorus added	Grams of pyrophosphate recovered
0.4	.0304	.0256
0.3	.0304	.0295
0.1	.0304	.0305
0.05	.0304	.0311
0.04	.0304	.0304
0.03	.0304	.0327
0.01	.0304	.0312

Four determinations were also made on the phytin sample without addition of inorganic phosphorus as follows:

Grams of phytin present	Grams of pyrophosphate recovered
0.4	.0053
0.3	.0022
0.2	.0011
0.1	.0003

The low results on solutions with high phytin content again indicate either a dragging down of inorganic phosphorus by the heavy precipitate of lead phytate, or actual combination between phytin and inorganic phosphates.

It was also thought possible that the particular form of the commercial phytin used might be accountable for these varying results. To test this, several series of determinations were made with the lead precipitation on extracts of feeding materials.

The method of procedure was as follows:

From 50 to 100 grams of material were extracted for three hours with a large volume of 0.2 percent hydrochloric acid. The resulting extract was filtered through paper by suction. Measured portions of this extract were placed in beakers, and a definite amount of di-sodium phosphate added, as before. The mixture was then precipitated with magnesia mixture and ammonia, using 10 c. c. of the former to 20 c. c. of the latter. After standing over night, the precipitate was filtered off and washed with dilute ammonia. After draining well, the paper with the precipitate was placed in a flask containing 250 c. c. of 0.8 percent nitric acid, and shaken until the paper and precipitate were thoroughly broken up. This solution was then filtered through a dry filter, and 200 c. c. of the filtrate placed in a 250 c. c. flask. After making neutral with ammonia, enough nitric acid was added to make the 250 c. c. of solution contain 0.2 percent of nitric acid. Lead nitrate solution was now added in slight excess, the flask filled to the mark, and digested for one hour at 60° C. The phytin was then removed by filtration through a dry filter, and after cooling, 200 c. c. of the filtrate was precipitated with official molybdate solution. The yellow precipitate was washed with diluted molybdate solution until free from lead, and phosphorus was then determined in the usual way.

This method gave the following results on wheat bran, and was also tried on alfalfa, which is thought to contain no phytin*.

One hundred grams of bran were extracted with 1500 c. c. of 0.2 percent hydrochloric acid containing 25 c. c. of 90 percent phenol.

To measured portions of this extract was added di-sodium phosphate solution equivalent to a final weight of .0246 gram of magnesium pyrophosphate.

SEPARATION OF INORGANIC PHOSPHORUS AND PHYTIN BY PRECIPITATION
WITH LEAD NITRATE IN ACID EXTRACT OF WHEAT BRAN

Volumes of extract	Pyrophosphate equivalent to inorganic phosphorus added	Pyrophosphate recovered	Calculated weight of pyrophosphate
C. C.	Grams	Grams	Grams
100	.0246	.0326	.0338
80	.0246	.0320	.0320
60	.0246	.0288	.0302
50	.0246	.0290	.0284
40	.0246	.0286	.0273
25	.0246	.0275	.0269
20	.0246	.0258	.0255
5	.0246	.0253	.0251
100	.0000	.0091	.....

*Hart and Tottingham: Journal of Biological Chemistry, Sept. 1909.

The fourth column refers to results which should have been obtained if .0091 gram of pyrophosphate is considered to represent the amount of inorganic phosphorus in the 100 c. c. of extract taken; and to this is added the blank, .0246 gram pyrophosphate, which had been added as di-sodium phosphate. For quantities of extract less than 100 c. c. proportional parts of the value .0091 were taken.

A similar series of determinations was made on alfalfa hay. Forty grams of alfalfa hay were extracted with 1000 c. c. of 0.2 percent hydrochloric acid containing 50 c. c. of 90 percent phenol. The inorganic phosphate added was again equivalent to .0246 gram pyrophosphate.

RECOVERY OF INORGANIC PHOSPHORUS ADDED TO ACID
EXTRACT OF ALFALFA

Volumes of extract	Pyrophosphate equivalent to inorganic phosphorus added	Pyrophosphate recovered	Calculated weight of pyrophosphate
C. C.	Grams	Grams	Grams
100	.0246	.0343	.0338
80	.0246	.0330	.0320
60	.0246	.0312	.0305
50	.0246	.0290	.0295
40	.0246	.0274	.0284
25	.0246	.0253	.0269
10	.0246	.0236	.0255
5	.0246	.0232	.0251
100	.0000	.0096	.....
100	.0000	.0090	.....

Although these results are not exact checks with the theoretical values, still they indicate, it is thought, that it may be possible entirely to recover the inorganic phosphorus added to these extracts; this in turn indicating in the case of wheat bran, that it is possible to make a quantitative separation of phytin and inorganic phosphorus.

Working with such extracts, however, results were always complicated by the uncertain amount of inorganic phosphorus in the extract itself. Figures representing this factor were obtained, it is true, but there was no means of proving whether they represented the actual values or not. Lack of a standard resulted in an element of uncertainty as to the above values of .0091, .0096 and .0090 for pyrophosphate in 100 c. c. of the extracts. although they are believed to be approximately correct.

It was thought that if a pure phytin could be prepared, free from inorganic phosphorus, it would, by eliminating this unknown factor, be possible to prove definitely whether a separation between phytin and inorganic phosphorus could be made quantitative.

It can be readily seen that such a preparation is attended by the same difficulties as is a quantitative determination of inorganic phosphorus in the presence of phytin.

While working on the relative solubilities of magnesium ammonium phosphate and phytin, it was found that although both substances are practically insoluble in 95 percent alcohol, a decided difference exists if the alcohol contains a very small quantity of mineral acid.

It was found further, that in 100-150 c. c. of 95 percent alcohol containing 0.2 percent of nitric acid, the quantities of magnesium ammonium phosphate commonly worked with were completely soluble, when the precipitated phosphate was shaken up with the reagent. On the other hand, phytin as precipitated from feeding materials appeared to be insoluble.

This suggested a means of separation, and at the same time a means of preparing inorganic-phosphorus-free phytin. With the latter object in view, a sample of phytin was prepared as follows:

A large quantity of wheat bran was finely ground, and extracted for several hours with 0.2 percent hydrochloric acid. The coarse bran was strained out by the use of linen, and then the extract was filtered by suction through paper in a Büchner funnel. A fairly clear filtrate was thus secured. This filtrate was precipitated with a large volume of magnesia mixture, and immediately filtered, as above, by suction. Magnesia mixture was used in order to have conditions similar to those of the regular quantitative method. The precipitate was washed thoroughly with water. This gave a very white, soft mass of fairly pure phytin. This precipitated phytin was then dissolved in a large volume of very dilute hydrochloric acid, and freed by filtration from a small residue of starchy material. The filtrate was again precipitated with magnesia mixture, and washed as before. This was repeated some 8 or 10 times. The washed precipitate was then macerated in a mortar with a small quantity of 95 percent alcohol containing 0.2 percent of nitric acid. A considerable volume of the same reagent was then added, and the whole mass shaken thoroughly in a flask until the lumps were broken up. This was then filtered again by suction, washed thoroughly with the alcohol reagent, and the maceration and filtration repeated several times. Finally the precipitate, after thorough washing with the acid-alcohol, was washed free from acid with absolute alcohol, and then dried at 50-60° C.

The product thus obtained was very white, and gave only an exceedingly faint test for inorganic phosphorus, the quantity of pyrophosphate from one gram of material being unweighable.

This test of its purity was made by precipitating the phytin in 0.2 percent nitric acid solution with lead nitrate, filtering and testing the filtrate with official molybdate solution. Tested directly, the sample would of course give no test, since the yellow precipitate would be totally suppressed by the phytin.

It is thought that separation was effected by the rapid filtration of the precipitated phytin, giving any inorganic phosphorus present, insufficient time to form magnesium ammonium phosphate, and also by the solvent action of the acid-alcohol on the inorganic phosphates present.

On this prepared phytin sample, determinations were made in an attempt to recover added inorganic phosphorus.

Using the lead nitrate method, better results were obtained than before, although exact recovery seemed impossible, due again doubtless to the slight solubility of the lead phytate formed, in the acid present, with a subsequent decomposition by the acid in the molybdate solution.

The acid-alcohol separation was accordingly tried on this prepared sample.

In each case 0.1 gram of phytin was dissolved in 100 c. c. of 0.2 percent hydrochloric acid. Inorganic phosphorus in the form of di-sodium phosphate was then added. The solution was then precipitated with magnesia mixture and ammonia. The next morning the solutions were filtered, and the precipitate washed, first with dilute ammonia, and then with 95 percent alcohol. After draining, the paper with the precipitate was placed in a flask containing 150 c. c. of 95 percent alcohol, which contained in turn, 0.2 percent of nitric acid. This flask was then shaken vigorously until the paper and precipitate were thoroughly disintegrated. The contents were then filtered through a dry filter, and 100 c. c. of filtrate placed in a beaker. This filtrate was then treated as follows:

Method I. Alcoholic filtrate was made alkaline with ammonia; filtered through a Gooch crucible; washed with alcohol; dissolved in dilute nitric acid, and precipitated with molybdate solution.

Method II. Same as Method I except that alcoholic filtrate was precipitated with magnesia mixture, instead of plain ammonia.

Method III. Five grams solid ammonium chloride were added to the acid-alcohol containing the paper and precipitate, and shaken up with the latter. The solution was then treated as in Method I.

Method IV. Alcoholic filtrate was precipitated with magnesia mixture; precipitate dissolved in dilute nitric acid, made alkaline, and precipitated direct with magnesia mixture, ignited and weighed in the usual way.

Determinations were made in triplicate. The blank on the inorganic phosphorus added, was equivalent to .0272 gram magnesium pyrophosphate.

COMPARISON OF METHODS FOR PRECIPITATING INORGANIC
PHOSPHORUS FROM ACID-ALCOHOL SOLUTION

		Pyrophosphate equivalent to inorganic phosphorus added	Magnesium pyrophosphate recovered	Corresponding amounts of phosphorus
		Grams	Grams	Grams
1	Method I.....	{ .0272	{ .0269	{ .0075
2		{ .0272	{ .0266	{ .0074
3		{ .0272	{ .0266	{ .0074
4	Method II.....	{ .0272	{ .0266	{ .0074
5		{ .0272	{ .0267	{ .0074
6		{ .0272	{ .0267	{ .0074
7	Method III.....	{ .0272	{ .0264	{ .0073
8		{ .0272	{ .0269	{ .0075
9		{ .0272	{ .0273	{ .0076
10	Method IV.....	{ .0272	{ .0275	{ .0077
11		{ .0272	{ .0272	{ .0076
12		{ .0272	{ .0273	{ .0076

Since all these determinations are within the limit of mechanical error the indication is that the separation was quantitative.

The method was also used on wheat middlings. Fifty grams were extracted for 3 hours with 1200 c. c. of 0.2 percent hydrochloric acid containing 25 c. c. of 90 percent phenol. The extract was filtered through paper by suction, and varying quantities used in the determinations. Inorganic phosphorus was added, and the method followed as outlined above, the alcoholic filtrate being treated as in Method I.

SEPARATION OF INORGANIC PHOSPHORUS AND PHYTIN BY
ACID ALCOHOL

No.	Pyrophosphate equivalent to inorganic phosphorus added	Volumes of extract	Magnesium pyrophosphate recovered	Calculated weights of pyrophosphate
	Grams	C. C.	Grams	Grams
13	.0272	100	.0355	.0355
14	.0272	100	.0354	.0355
15	.0272	80	.0340	.0339
16	.0272	60	.0312	.0322
17	.0272	50	.0311	.0314
18	.0272	40	.0303	.0306
19	.0272	25	.0293	.0293
20	.0272	10	.0288	.0281
21	.0272	5	.0276	.0277
22	.0000	100	.0083	.....
23	.0000	100	.0082	.....
24	.0000	100	.0082	.....

Taking into consideration mechanical errors, etc., the results are as close as could be expected.

Using Method II as detailed on page 474, some common feeding materials were tested for inorganic phosphorus. Total phosphorus was determined by the Neumann method. Determinations were made in triplicate.

These triplicate determinations were made on separate 10-gram samples of the feeding material, and not on the same solution.

TOTAL AND INORGANIC PHOSPHORUS IN CERTAIN FOODSTUFFS.

	Total phosphorus	Inorganic phosphorus	Average inorganic phosphorus
	Percent	Percent	Percent
Alfalfa	0.23	{ 0.135 - 0.136 { 0.136	0.136
Clover hay.....	0.171	{ 0.104 - 0.103 { 0.104	0.104
Corn meal.....	0.266	{ 0.040 - 0.042 { lost	0.041
Soy beans.. . . .	0.547	{ 0.054 - 0.054 { lost	0.054
Cow peas.....	0.445	{ 0.056 - 0.055 { 0.056	0.056
Oats.....	0.397	{ 0.061 - 0.059 { lost	0.060
Wheat.....	0.394	{ 0.036 - 0.038 { 0.035	0.036
Brewer's grains	0.452	{ 0.012 - 0.011 { 0.015	0.013
Distiller's grains, from corn	0.366	{ 0.050 - 0.049 { 0.049	0.049
Rice polish.. . . .	0.60	{ 0.026 - 0.027 { 0.027	0.027

Since these triplicates represent separate samples of the feeding material, their close agreement indicates that this method is consistently workable.

The elimination, which seems to have been attained, of organic phosphorus compounds from the solution in which the inorganic phosphorus is finally precipitated, precludes the possibility of magnesium oxide or proteid phosphorus being present as an impurity in the inorganic phosphorus precipitate. Further, in those samples

which contain phytin, the acid-alcohol separation eliminates the factors (1) of suppression of the yellow precipitate by the phytin, and (2) of decomposition of the phytin by acid in the reagents used in precipitating inorganic phosphorus. Inorganic phosphorus alone appears to be present in the final solution obtained, and a clear-cut, normal, phosphorus determination results.

After considerable use of phenol in this precautionary way, we made a further test of its value on middlings, alfalfa and distiller's grains. The results were as follows:

EFFECT OF PHENOL IN INORGANIC PHOSPHORUS ESTIMATION

Foodstuff	Total phosphorus	No phenol	10 c. c. phenol	15 c. c. phenol
Middlings (1).....	.762	.046	....	.046
Middlings (2).....	....	.059	.061	.060
Alfalfa .....	....	.130	.130	.128
Distiller's grains.....	.811	.407	.414	.414

These determinations were made by our final acid-alcohol method. These results incline us to the belief that in these feeds, at least, there is not an appreciable splitting off of inorganic from organic phosphorus compounds by enzymes during the course of our three-hour extraction, and hence that the use of phenol is probably not necessary. In a further test of this point we got exactly the same figure, .0459 percent, for inorganic phosphorus in wheat middlings, both with and without the presence of phenol during extraction.

In another test of the same point we determined inorganic phosphorus in wheat middlings, distiller's grains and alfalfa, both with and without the presence of phenol during extraction. The differences due to the presence of phenol were immaterial. There was no evidence of benefit from the use of phenol, and hence it seems much preferable not to introduce this strong reagent into the determination.

In an attempt to shorten our provisional method we made three sets of determinations of inorganic phosphorus on wheat middlings, two on distiller's grains, and two on alfalfa, in which we sought to determine whether a precipitation with magnesia mixture should follow the separation of inorganic phosphorus from phytin in acid alcohol, or whether we might evaporate the acid-alcohol solution of inorganic phosphorus, take up with acid, and proceed with the final estimation of phosphorus in the official gravimetric way by precipitation, first with acid molybdate solution, then with magnesia mixture, and burning to the pyrophosphate.

In all cases the results by these two methods were either absolutely or practically identical, and hence we conclude that a magnesia precipitation after the acid-alcohol separation of phytin and inorganic phosphorus is unnecessary.

A similar test was made of acid and neutral molybdate solutions in the final precipitation of inorganic phosphorus, in the latter case only sufficient nitric acid being added to cause a separation of the yellow precipitate. This comparison was made by our final method, in which the phosphorus estimation is made directly after the acid-alcohol separation of inorganic phosphorus and phytin, and also by the earlier provisional method in which a magnesia precipitation intervened between the acid-alcohol separation and the phosphorus estimation. The results were practically the same, and hence our only basis for choice between these methods was ease and rapidity of manipulation.

ROUTINE METHOD

In detail the final method adopted for inorganic phosphorus in plant substances is as follows:

Pour exactly 300 c. c. of .2 percent hydrochloric acid onto 10 grams of the finely ground sample in a 400 c. c. Florence flask. Close with a rubber stopper, and shake at intervals of 5 minutes for three hours. Filter the extract through dry filters into dry flasks.

Owing to the character of the extracts from certain feeding materials, especially soy beans and oats, it may be necessary to use gentle suction toward the end of the filtration. To prevent rupture of the filter paper, a platinum cone may be used. A Witt filtering apparatus is a convenience in this work. Filtration of the extract is facilitated in many cases by the use of about one inch of fine sand in the point of the filter paper.

Measure out a 250 c. c. portion of this filtered extract, and precipitate in a 400 c. c. beaker with 15 c. c. of magnesia mixture and 30 c. c. of strong ammonia. Allow to stand over night, and filter through doubled 11 cm. S. & S. No. 595 filters, taking care to decant as long as possible without pouring out the precipitate. Then complete the transfer of the precipitate to the paper.

This filtration also may be hastened toward the end by suction, using a platinum cone to keep the paper intact.

This precipitate consists of magnesium ammonium phosphate, together with phytin, when this compound is present in the substance involved, and small quantities of variously colored unknowns.

Wash several times with 2.5 percent ammonia, and then several times with 95 percent alcohol until free from ammonia. This result may be hastened by also washing with alcohol between the

two filters. The alcohol clears up the precipitate by dissolving out a large part of the variously colored compounds other than phytin and magnesium ammonium phosphate. Allow the remaining precipitate to drain, and then spread out the inner paper on the top of the funnel, and allow the alcohol to evaporate.

When practically dry, place this inner paper with the precipitate into an Erlenmeyer flask. Add 100 c. c. of 95 percent alcohol containing 0.2 percent of nitric acid. Close the flask with a rubber stopper and shake vigorously until the paper is thoroughly broken up. If the precipitate is flaky, and refuses to break up on shaking, allow to stand in the acid-alcohol over night.

Now filter through a dry, double filter into a dry flask. Pipette out 75 c. c. of the filtrate into a small beaker, and evaporate almost but not quite to dryness. Dissolve in dilute nitric acid, and filter if necessary; then determine phosphorus in the usual gravimetric way, by precipitation first with acid molybdate solution, later with magnesia mixture, and then burning to the pyrophosphate. Re-precipitation has been found to be unnecessary.

The result as obtained above represents 6.25 grams out of the original 10 grams of material, and so to reduce to a 1-gram basis multiply by .16.

ESTIMATION OF INORGANIC PHOSPHORUS IN ANIMAL TISSUES

The most valuable method known to us for the determination of inorganic phosphorus in animal tissues has been that of Emmet and Grindley*. This method was worked out for use on muscular tissue, and for this purpose we have found it to be accurate and satisfactory. Attempts to use this excellent method with tissues other than muscle, however, showed further study of the problem to be necessary. After thorough trial we have adopted a method for our work, which is equally applicable to muscle, liver, kidney and brain, and which while giving identical results with Emmet and Grindley's method when used on muscle, has the advantage over this method of being somewhat more easily workable, and of saving one precipitation which is often necessary in the use of Emmet and Grindley's method on muscle, and which is always necessary when this method is used on liver, kidney and brain.

The difficulties encountered in our attempts to make general use of Emmet and Grindley's method for muscle, on other tissues, were in the filtration of the cold-water extracts, and in getting uncontaminated precipitates of inorganic phosphorus.

Cold-water extracts of liver, kidney and brain are not filterable by usual methods. Coagulation by boiling renders easy the filtration of liver extract, and renders possible the filtration of the extract of kidney, but does not assist materially in the filtration of the extract of brain.

Further—after finding workable methods for coagulating and filtering the extracts, the neutral molybdate precipitation of Emmet and Grindley's method gave us bulky, flocculent, organic precipitates, especially in the case of liver, kidney and brain, which by obscuring the formation of the yellow precipitate, rendered impossible an accurate judgment as to the amount of acid necessary to the completion of the precipitation. These bulky, flocculent precipitates redissolve in ammonia, and reappear in the precipitate with magnesia mixture. The possibility of adding phosphorus or magnesia to the pyrophosphate through their presence in the above-mentioned flocculent, organic precipitates, contributes another item of uncertainty and possible inaccuracy to the use of this method when we attempt to apply it to liver, kidney and brain.

*Journ. Am. Chem. Soc., Vol. 28, p. 25.

In our study of methods of preparation of the water-extract for filtration, we found that boiling and treatment with ammonium sulphate would render the extracts of any of these tissues readily filterable.

After a trial of various methods on brain, we found most satisfactory results obtainable by boiling the extract for a few moments, the exact time being immaterial, then adding ammonium sulphate in solution, and continuing to boil for about ten minutes.

The various difficulties of precipitation and filtration, incident to the preliminary molybdate precipitation, were obviated by direct precipitation of the inorganic phosphorus, from the coagulated and filtered extracts, with magnesia mixture. This gives us a precipitate of approximate purity, results in a very great saving of time in filtration, and obviates the possibility of hydrolysis of organic phosphorus compounds by the nitric acid used in precipitation with ammonium molybdate.

This precipitate with magnesia mixture is dissolved and reprecipitated, first with official acid molybdate solution, and then again with magnesia mixture in the usual way, and the phosphorus weighed as the pyrophosphate.

The essentials of the new method are (1) extraction of the inorganic phosphates with hot water, (2) boiling the extracts with ammonium sulphate to render them filterable, (3) direct preliminary precipitation with magnesia mixture, and (4) a number of important mechanical details of procedure.

Our first work on this problem was an attempt to use Emmet and Grindley's method for muscle, on liver, kidney and brain. We proceeded as follows:

The muscle extract was prepared with cold water according to Grindley*.

The liver extract was prepared in the same way, but was heated on the steam bath in order to render it filterable through paper.

The kidney extract was prepared in the same way as the liver extract, but was not filterable through paper. This solution was filtered through sand in the cone of a linen filter such as is used in crude-fiber determinations.

The brain extract contains practically the whole of the brain substance, the addition of water simply diluting the paste. It was not filterable hot or cold, through paper, linen or sand. This solution was rendered filterable by bringing to a boil, adding ammonium sulphate, and continuing to boil for ten minutes. It was then passed through sand on linen.

*Journ. Am. Chem. Soc., Vol. 27, p. 638.

We now had (1) a cold-water extract of muscle, (2) hot-water extracts of liver and kidney, and (3) a hot-water-ammonium sulphate extract of brain.

Measured portions were concentrated by boiling in order to reduce the bulk and to coagulate proteids, and were then filtered through paper, and washed with water, but not without difficulty in the case of liver, kidney and brain.

Proceeding by the method of Emmet and Grindley, we treated the extracts with neutral molybdate solution and 3 c. c. of 1.20 nitric acid, as specified, to effect the separation of the yellow precipitate.

In the case of liver, kidney and brain, it was found that 3 c. c. of nitric acid were insufficient. Two cubic centimeters in addition, five in all, were found necessary, because of the abundance of organic matter in these solutions, and 10 grams of ammonium nitrate, instead of 5 grams as specified by Emmet and Grindley, were found necessary with the brain, where we had added ammonium sulphate.

The results were not satisfactory. The liver, kidney and brain extracts gave abundant flocculent precipitates, greenish colored with the liver, nearly white in the case of the brain, and of an intermediate grayish color with the kidney. These contaminations so masked the yellow precipitate that accurate judgment as to the completeness of the precipitation was impossible.

The precipitates were filtered out, and reprecipitated with official acid molybdate solution. The contaminations persisted in all cases except with muscle.

The yellow precipitates were redissolved, and precipitated in the usual way with magnesia mixture.

These last precipitates were obviously impure. With the brain an abundant, white, flocculent contamination was present, while with the liver and kidney the precipitates were highly colored.

The results with muscle were satisfactory.

The pyrophosphates from liver, kidney and brain were boiled with nitric acid, and precipitated once more with magnesia mixture, but the results were of doubtful value.

We next attempted the precipitation of inorganic phosphates with dilute solutions of calcium and ferric chlorides. The gelatinous precipitate was difficult to wash, and probably on this account, gave slightly higher results on muscle than did Emmet and Grindley's method.

The direct precipitation of the concentrated cold-water extract of muscle with magnesia mixture was now tried, followed by precipitation, first with official molybdate solution,

and then with magnesia mixture, and this gave results identical with others obtained by the Emmet and Grindley method.

This method was therefore given a careful trial. The points which we sought to determine were (1) whether or not the use of heat and ammonium sulphate gave the same inorganic phosphorus content in the extract as Grindley's cold-water extraction, and (2) whether or not the direct precipitation with magnesia mixture effected a complete precipitation of the inorganic phosphates without bringing down other phosphorus compounds to contaminate the pyrophosphate.

COMPARISON OF METHODS FOR THE ESTIMATION OF
INORGANIC PHOSPHORUS IN MEAT

	Grams magnesium pyrophosphate per gram fresh substance		
	Emmet and Grindley's Method Precipitated (1) with neutral molybdate and minimum of acid, (2) with official acid mo- lybdate, (3) with mag- nesia mixture, and (4) with magnesia mixture	Magnesia Method Precipitated (1) with magnesia mixture, (2) with official acid mo- lybdate, and (3) with magnesia mixture	Acid-Alcohol Method Precipitated (1) with magnesia mixture, and dissolved in acid alco- hol, (2) with magnesia mixture, (3) with official acid molybdate, and (4) with magnesia mixture
Muscle sample No. 1	.0049	.0051	.0048
Cold-water extract	.0049 .0047	.0051 .0050	.0048 .0047
Muscle sample No. 1	.0050	.0050	.0049
Boiled with ammonium sulphate	.0051 .0049	.0050 .0050	.0049 .0051
Muscle sample No. 2	.....	.0056	.0053
Cold-water extract	..... ... ..	.0053 .0054	.0053 .0054
Muscle sample No. 2	.....	.0056	.....
Hot-water extract	..... .....	.0056 .0056	..... .....
Muscle sample No. 2	.0054	.0055	.....
Boiled with ammonium sulphate	.0054 .0054	.0055 .0054	..... .....
Liver sample No. 1	.....	.0049	.0048
Hot-water extract; am- monium sulphate added, then concentrated by boiling	..... .....	.0049 .0050	.0049 .0049
Liver sample No. 1	.....	.0047	.....
Boiled with ammonium sulphate	..... .....	.0049 .0048	..... .....

The above table sets forth our results in this work. The figures represent the weight of pyrophosphate from the inorganic phosphorus in one gram of meat.

In making these determinations the amount of meat represented by each precipitate was about three grams.

With a cold-water extract of muscle sample No. 1, we compared Emmet and Grindley's method, with our magnesia method, and also with our acid-alcohol method, which we have adopted for vegetable substances.

The triplicates agree almost exactly, and the determinations by the different methods also agree, the differences being well within the limit of legitimate error of work. This excellent agreement in results by three different methods, shows that the inorganic phosphorus of flesh is a definite part thereof, and that it is susceptible of accurate estimation.

The agreement three times each by three well-considered methods also shows that they are all probably correct.

The acid-alcohol method is as long as the Emmet and Grindley method, and was included in this trial because its agreement with the other methods would not only strengthen them, but would also tend to sustain our method for inorganic phosphorus on vegetable substances. The results fulfill these desired conditions.

The magnesia method is decidedly the best of the three, however, because of the aforementioned advantages of brevity, purity of precipitates, and ease and certainty of manipulation.

A second extract of muscle sample No. 1 was prepared by boiling with ammonium sulphate, for the purpose of ascertaining what effect, if any, this salt might have in our estimation of inorganic phosphorus in other tissues, especially in kidney and brain, where we have found ammonium sulphate especially useful in the preparation of the extracts.

The close agreement of our triplicates and the very close agreement of the results by each of the three methods, and the agreement of determinations on this hot-water-ammonium sulphate extract with the equally satisfactory results on the cold-water extract show that ammonium sulphate is without effect on the estimation of inorganic phosphorus, due regard being given, of course, in the Emmet and Grindley method, to the sulphuric acid radical which this salt introduces into the solution.

With a second sample of muscle we compared the magnesia method and the acid-alcohol method on a cold-water extract, with the magnesia method on a hot-water extract, and with the Emmet and Grindley, and the magnesia methods on a hot-water-ammonium sulphate extract.

The three methods again checked remarkably well, and there appears to be no difference in the inorganic phosphorus contents of the cold-water, the hot-water, and the hot-water-ammonium sulphate extracts.

With a sample of hog liver we compared two methods of use of ammonium sulphate. In one case the tissue was boiled with the sulphate, as in the preparation of the extract of brain and kidney, while in the other the sulphate was added to the filtered hot-water extract, and was present only during the concentration of the extract by boiling.

The magnesia method once more gave identical results with those from the acid-alcohol method, and the presence of ammonium sulphate was again found to be without demonstrable effect, either on the extraction or the estimation of the inorganic phosphorus.

In making a final comparison of the three methods, it may be said that the amounts of phosphorus found by the three are practically identical, but with slightly higher results, just perceptible, and well within the limit of error of work, in favor of the magnesia method.

The details of our magnesia method for the estimation of inorganic phosphorus in muscle, liver, kidney and brain are as follows:

PREPARATION OF SAMPLES

The animals whose tissues are to be compared must be killed in the same way, and should be quickly and thoroughly bled in order that the blood content of the tissues may be the result of natural conditions, rather than differences in method of killing, such as varying lengths of time between stunning and bleeding.

In order to get a definite product for analysis, the brain should be freed from its vascular investing coats by carefully stripping these away with forceps.

The gall bladder should be removed from the liver, and also such tough connective tissues at the base of the organ as would interfere with the free grinding of the functional liver tissue.

The kidneys are removed from their capsules; the fat, blood-vessels and ureter are removed with scissors from the hilus, and the interior of the organ is opened and freed from contents.

The muscular tissue is freed from superficial fat and from tendons.

All work is done as promptly as possible, with all possible precautions to prevent evaporation.

The tissues are prepared for sampling by grinding with an "Eclipse" grinder. An electric motor attachment is a great saver of labor, and by facilitating the work, helps to minimize loss of moisture by evaporation.

The materials are ground three times, with careful mixing between grindings, and samples are placed in glass jars which have screw tops lined with rubber. The bottles of ground meat are then frozen up as quickly as possible, and kept in this condition until the determination can be started.

PREPARATION OF EXTRACTS

Weigh by difference from closed weighing bottles, 20-gram portions of liver, kidney or muscle into 400 c. c. beakers. In the case of brain, weigh out likewise about 20 grams, but divide it between two 250 c. c. beakers.

Beat up in a little cold water, to separate the particles of meat; add 200 c. c. of boiling water for muscle, liver and kidney, and 100 c. c. of the same for each half of the brain sample, and bring to boiling. Add ammonium sulphate in solution equivalent to 1 gram for each 10 grams of muscle, liver and kidney, and to 4 grams of the same for each 10 grams of brain, and continue to boil for 19 minutes.

Remove from the flame; allow to settle for a moment, and decant the boiling-hot liquid onto 18 cm. folded paper filters, for muscle liver and kidney, and onto sand in an 18 cm. linen filter in the case of brain.

Add 100 c. c. of boiling water to the liver, kidney and muscle remaining in the beakers, and in the case of brain 50 c. c. of 0.1 percent boiling ammonium sulphate solution to each half of the sample.

Stir for about 8 minutes in the case of liver, kidney and muscle, and for about one minute with brain, and decant the liquid onto the filter. Repeat this addition of 100 c. c. portions of water, (50 c. c. of 0.1 percent ammonium sulphate with brain), stirring and decanting five times; repeat three times more with 50 c. c. portions of boiling water with liver, kidney and muscle, and with 25 c. c. portions of 0.1 percent ammonium sulphate solution with brain. With the eighth portion of water, (or 0.1 percent ammonium sulphate), throw the entire contents of the beaker onto the filter, and wash with hot water from a wash bottle, with liver, kidney and muscle, and with hot 0.1 percent ammonium sulphate solution for brain. The two portions of brain extract are combined. The extracts of all the tissues are then made up to 1000 c. c.

It is especially important that the brain extracts be kept and handled boiling-hot. If the sand filter clogs during the filtration, this process may be greatly facilitated by lightly scratching over the surface of the sand with a stirring rod, taking care not to touch the linen.

It is not advisable to attempt to handle more than 10 grams of brain in one beaker, on account of the necessity of completing the filtration promptly while the solution is hot.

DETERMINATION OF INORGANIC PHOSPHORUS

Measure out 250 c. c. portions of the extract into 400 c. c. beakers. Evaporate to 50 c. c. by gentle boiling; filter while hot, and wash with boiling water. Cool, and add 10 c. c. magnesia mixture, stirring freely; allow to stand 15 minutes, and add 10 c. c. of ammonia, specific gravity .90. Cover, and allow to stand over night.

On the next morning filter, and wash the precipitate with 2.5 percent ammonia water. Dissolve the precipitate on the filter paper with dilute nitric acid into the same beaker in which the first precipitation was made, and wash the papers thoroughly with hot water.

Render the resulting solutions nearly neutral; add 5 grams of ammonium nitrate; heat to 65° C.; add 50 c. c. of official acid molybdate solution, and keep contents at 60°, stirring frequently, for 2 hours.

Then continue in the usual way for the gravimetric estimation of phosphorus as the pyrophosphate.*

Each 250 c. c. of the extract will, of course, represent one-fourth of the original sample, and therefore will contain the inorganic phosphorus from about 5 grams of fresh substance.

SUMMARY

Inorganic phosphorus in plant and animal tissues appears to be susceptible of practically as accurate quantitative estimation as in ordinary inorganic analysis.

The principle of our method of inorganic phosphorus determination in plant substances is (1) extraction of the inorganic phosphorus with .2 percent hydrochloric acid, (2) precipitation with magnesia mixture, nucleic acid being removed in solution, (3) dissolving the inorganic phosphorus out of this precipitate by the use of acid-alcohol, phytin remaining behind with the paper, (4) evaporation of the alcohol from the acid-alcohol solution of the inorganic phosphates, followed by solution of the phosphates in acid and a gravimetric estimation of phosphorus in the usual way by

*Bul. 108, Bur. Chem., U. S. Dept. Agr.

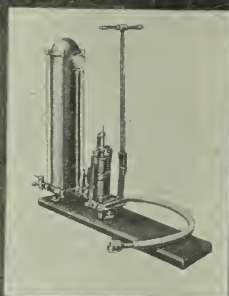
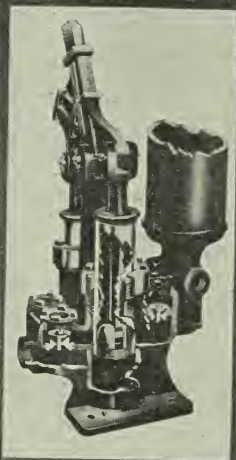
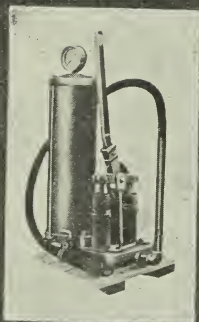
precipitation, (5) first with official acid molybdate solution and then, (6) with magnesia mixture, and finally (7) burning to pyrophosphate.

Where necessary to prevent enzyme action phenol may be used in the extractive reagent.

This method is somewhat tedious but is clean-cut, workable and exact.

The method for animal substances is in brief (1) extraction with boiling ammonium sulphate solution, (2) filtration, concentration by boiling, and precipitation with magnesia mixture, (3) a gravimetric estimation of phosphorus by precipitation, first with official molybdate solution, then (4) with magnesia mixture, and finally (5) burning to the pyrophosphate.

This method is equally applicable to muscle, liver, kidney and brain.



Five types of large hand pumps

Hardie
Brown

Goulds

Deming
Brown

BULLETIN

OF THE

Ohio Agricultural Experiment Station

NUMBER 216

APRIL, 1910

SPRAYING MACHINERY

By W. H. GOODWIN

Spraying machinery has become of special importance during recent years through the interest in fruit growing aroused among farmers and fruit growers in general. Experiments carried on by this Station have proved beyond a doubt that apples and other fruits of excellent quality can be profitably raised in Ohio. The unusually high price which good fruit has commanded during the past five years has tended to attract many who ordinarily would not consider orcharding as a vocation.

The fact that Ohio has a large amount of land which is unsuited to farming but will make excellent orchard land, and that the northern part of Ohio is tempered by the Great Lakes, has also stimulated fruit growers to make use of what nature has provided for them. The intense competition of the Western states in shipping fruit into a fruit-growing region and selling it where poor, home-grown fruit could not be marketed, has aroused a feeling that Ohio orchardists could raise fruit that was just as good, and they have demonstrated that this is true. These orchardists only needed to have their pride stirred up to set them at work to duplicate or excel western achievements.

Because so many people are totally unacquainted with spraying operations and spraying machinery, the preparation of this bulletin has been undertaken. It is the hope of the author that it may aid many of the uninitiated in the selection of a machine which will do what is desired of it.

Spraying machinery has been passing through a period of transition during the last decade, and pumps used for different kinds of spraying are rapidly becoming special purpose machines, designed to spray some certain crop or series of crops, which are treated in a similar manner. For example, this evolution has developed a traction machine of large capacity which will furnish liquids at high pressures to do grape, field and potato spraying thoroughly with a minimum of expense for labor and material. This is usually a two-wheeled, traction-power type of machine, in which the power is transmitted from the wheels by gears, chains, eccentrics, or cams, and the horse does the work instead of a man at the end of a pump handle.

Sometimes a man has made the acquaintance of some particular make of machine and knows its little faults so well that it may be better for him to retain this machine rather than purchase some simpler, less troublesome type of pump. On the other hand, in the present period of evolution in spraying machinery, it will often pay a man well to discard his old favorite for some more modern, more efficient type of machine which is better suited to his special line of work and better adapted to the particular conditions existing in his locality.

FACTORS TO BE CONSIDERED IN CHOOSING A SPRAY PUMP

Capacity, which involves.....	{ Size Weight
Simplicity, which involves ...	{ Accessibility of parts Ease of repair
Durability, depending upon ..	{ Quality of material Kind of material Workmanship Correct mechanical principles and designs Strength Weight
Cost, determined by.....	{ Capacity of pump Type of pump Amount of labor involved in manufacturing Material used Quality of material

Capacity. A pump of larger capacity than is actually needed will always prove more satisfactory than one which falls short of the demands made upon it. As trees and orchards increase in size, the importance of having a machine which will enable the fruit grower to cover a considerable area quite rapidly, becomes apparent. The grower must either purchase a new machine of larger capacity or look ahead at the outset, and provide for the future. Four acres of good bearing orchard is worthy of a power sprayer if the best

results are desired, and nothing of smaller capacity than a large hand pump should be considered. A larger or smaller orchard will require a pump proportionately larger or smaller, but there is a limit for even the largest machines, and twenty acres of large trees is about all one large power sprayer was ever designed to spray.

Simplicity. Spray pumps should be as simple as possible, with a minimum of parts which ordinarily require attention. These parts should be easily replaced when worn, and should not be expensive when replacement becomes necessary. The ideal sought demands, *ease of repair*, a minimum of parts, and these *readily accessible*, when worn, or not working properly. Leaky packing, clogged valves, worn out valves, valve seats, cylinder liners, and plunger packings or cups must all be considered before choosing a pump that will fulfill its mission and serve the purpose for which it was purchased.

Durability. On the *quality* and *kind of material*, the excellence of the *workmanship*, together with *weight* and *strength* depends the *durability* or lasting qualities of the machine. Good design is also an important factor. *Cheapness* quite often means that inferior material has been used, and that inefficient or negligent laborers, who slight their work by accident or design, have been employed in the pump's manufacture.

Designers and builders of pumps often seem unwilling to adopt new ideas or better designs, and continue to build the same type of machine that they did ten or twelve years ago. Such machines will squirt liquid after a fashion, but they do not give the purchaser the returns desired with a minimum of expense for labor and repairs.

Some machines were never intended by their designers to pump gritty spray solutions, oil emulsions, caustic solutions, or acid oils in emulsion form, and consequently will not prove satisfactory. The *efficiency* of a pump depends largely upon the construction of its valves, valve-seats, plunger, cylinder and stuffing box, if built with the last. Air chambers are also very important, hence these subjects will be taken up under separate heads.

The *body* or *frame* of the pump should be heavy and strong enough to withstand hard usage and excessive strain. Bearings are often too short, gears too narrow and too light in weight, oil cups are omitted where they are needed, and the frame upon which the machine is mounted is so light that it is warped and buckled at every stroke of the pump.

Air Chambers are often omitted on small pumps and some large machines are equipped with very small ones. A barrel pump is greatly improved by the addition of an air chamber five or six inches

in diameter and about two feet long. Intake and hose supply-pipes must be from a point near the bottom of the chamber or the value of the resilient column of air is lost. The value of an air chamber lies in the even pressure obtained, in the taking away of the heavy shock upon valves, and of the sudden strain often put on other parts of a pump. A good air chamber also eases the labor of the man at the handle of the pump or of the engine which is furnishing the power. The liquid in the air chamber is often unagitated unless some provision in design has been made so that the opening of a nozzle cut-off agitates the liquid contained in the air chamber, in addition to the agitation caused by the supply of liquid being forced into the chamber.

Cylinders. Of cylinders we have several types, but no spray pump cylinder should be made of cast iron or steel, except for spraying miscible oils and lime-sulfur solution. Brass tubing of heavy weight and threaded to fit the cylinder head is quite a common design. Some makers use a brass tubing cylinder clamped between the cylinder heads. Others use a solid cast chamber with some form of a brass liner or cylinder inside of the cast iron one. The most durable and the one least affected by spray solutions is undoubtedly the heavy, cast iron cylinder enameled with porcelain. The chief obstacle to the use of such a cylinder has been to get an even coat of enamel on the inside of the machined cylinder-casting, or a plunger-packing or cup which would have sufficient resiliency to adapt itself to the uneven wall of the cylinder. Some of the manufacturers seem to have solved this problem in a satisfactory way, while others claim it is but a partial success when used in the type of machine which they manufacture.

Valves. Kinds of valves are almost too numerous to mention if one takes into account the variations in each class. We may divide them into four classes: ball, poppet, swing-check and steam-check valves. For the first, three materials are used: rubber, steel and bronze, the latter material being of course the most durable for all-round work. Of the styles of poppet there are many which may be classified as follows: plain, square-faced poppet valves with rod-guide to hold them in position as in Fig. 1 of the plate showing valves. Fig. 2 shows how uneven is the wear on such a valve. Fig. 3 shows a plain poppet valve with wing-blades to right it instead of a rod. Fig. 5 is a bevel-faced, wing-guided poppet valve, which approaches a large ball valve in durability and efficiency, when it is made so that it will rotate. Fig. 4 shows a modified form of a wing-guided poppet valve, with a rubber or leather ring to improve its efficiency in helping to retain the liquid above it. Figs. 6, 8 and 10 are ball valves.

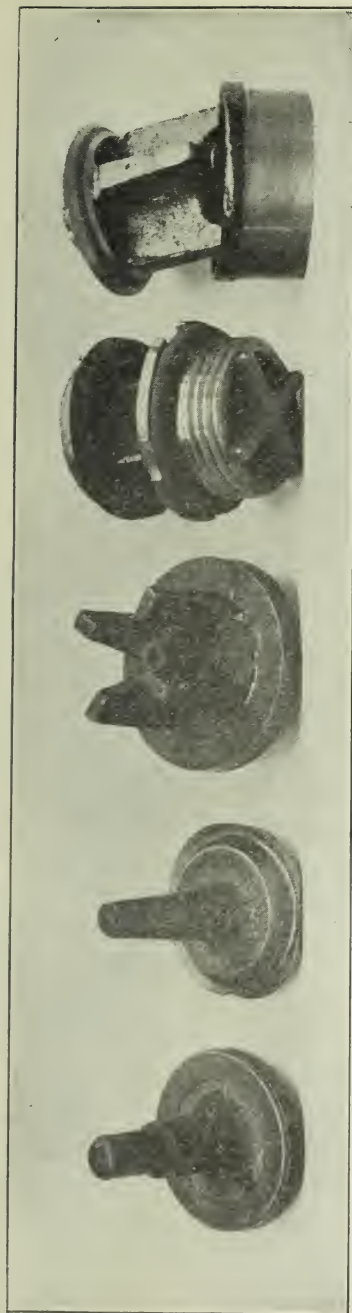


Fig. 1 Fig. 2 Fig. 3 Fig. 4 Fig. 5

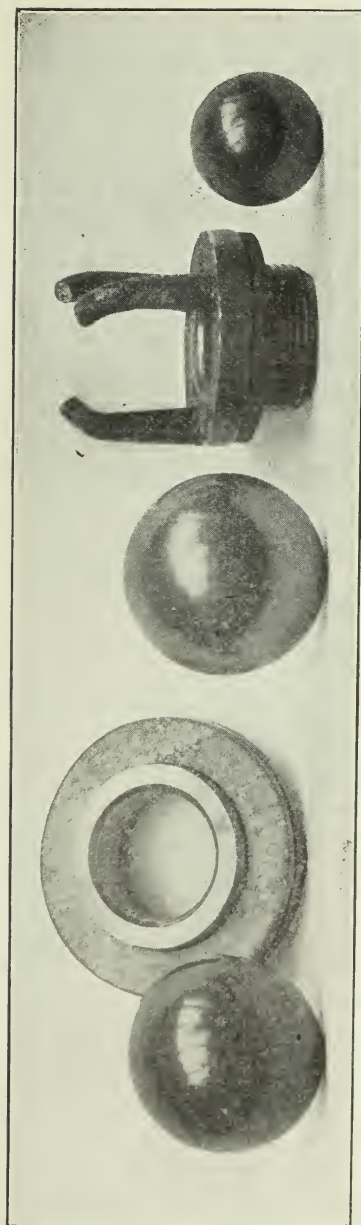
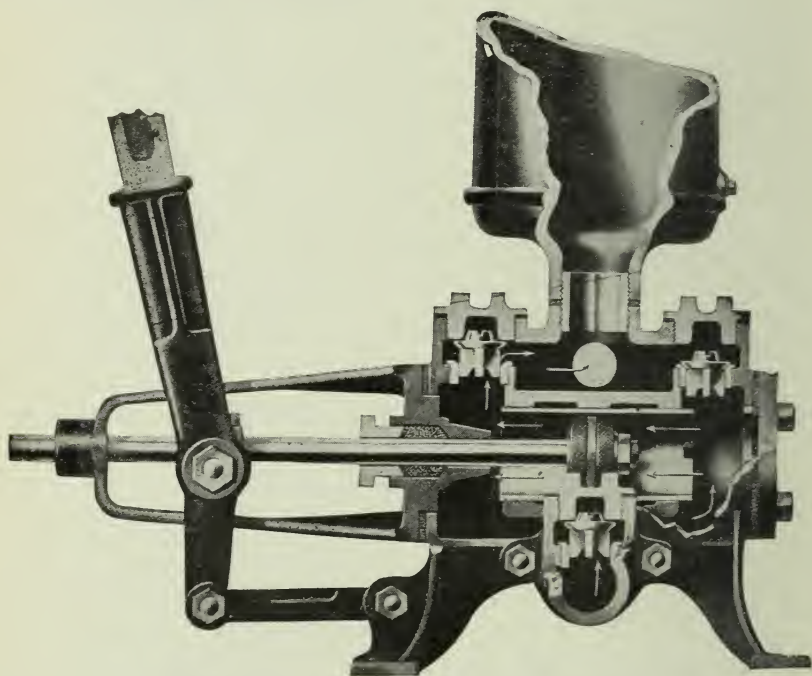


Fig. 6 Fig. 7 Fig. 8 Fig. 9 Fig. 10

PLATE SHOWING VALVES

Figs. 6 and 8, are about the desired size to give the maximum of durability and efficiency. The minimum size, shown in Fig. 10, should not be less than three-quarters inch in diameter, and the upward range may extend to one and three-eighths inch in diameter, as in Fig. 8, for the maximum size, in large power pump. Small hand pumps may have ball valves as small as one-half inch in diameter. Poppet valves should be much larger in proportion to the amount of liquid passing through them than should the ball-valves. It is well to remember that, when the pump is running the valve becomes as much lighter in weight as is the weight of the amount of liquid it displaces, hence a much heavier valve can be used than a novice might suppose.



Goulds double acting pump showing arrangement of parts.

Swing check and steam check valves are types designed for use in water and steam pipes. Both types work well in spray pumps when they are new, but their lasting qualities in a spraying machine are yet to be demonstrated. A flat face in any valve wears unevenly and makes a leaky valve when in combination with a flat valve-seat. Threads or waste sucked through the strainer often lodge across the square edge of the valve-seat and hold grit, hence the desirability of having bevel edges in valve-seats so that such material will not catch.

Valve Seats. Valve seats are built to receive the type of the valve used, and are made correspondingly cheap or costly. Iron valve-seats are common, and are usually found in ordinary well-pumps. Some few makers use a rubber or leather ring as a secondary seat, which prevents back flow, through its elasticity, when the weight of the liquid or the pressure above holds the valve down. One company has equipped a pump with hard rubber valve seats, but the majority of the manufacturers use a removable brass valve-seat. Strange to say, no company, as far as I know, seems to have tried to build valve-seats of the harder, non-corrodible alloys—that is, those not affected by spray solutions. In valves, a large part of the wear is on the valve-seat, especially in the case of the bronze-ball types. The ball may wear some, but constant turning keeps it a perfect sphere, while the valve-seat is hammered and worn away at every stroke of the pump, making plain the desirability of using a harder metal for a valve-seat than is used for the ball. I think that any man who has had experience with pressure pumps will also concede that a large ball-valve is the most efficient and durable type made, especially for gritty solutions such as many of the spray mixtures are known to be. Figs. 7 and 9 show valve-seats and the accompanying balls are on the left and right of the valve seats.

Plungers. Plungers are fitted with various types of packing. Very few pumps are equipped by their makers with poor packing, but leather hardens so rapidly that it is almost worthless as a packing for a spray pump, and hence should not be used for plunger-cups when other material can be obtained. The following materials are used for plunger packings: hemp, candlewicking, steam packing, paraffine canvas, cotton cloth reinforced with rubber, and various other packings which go under trade names. Most of the packings are treated with oils, graphite or paraffin, but this does not include those in which rubber has been incorporated. Plungers are usually designed to carry a special kind of packing and they work better with that kind of packing than with almost any substitute. A packing that is cheap, easily renewed or replaced, and that will last for a considerable period of time without wearing away so rapidly that it requires constant attention to keep it in shape, is the most desirable.

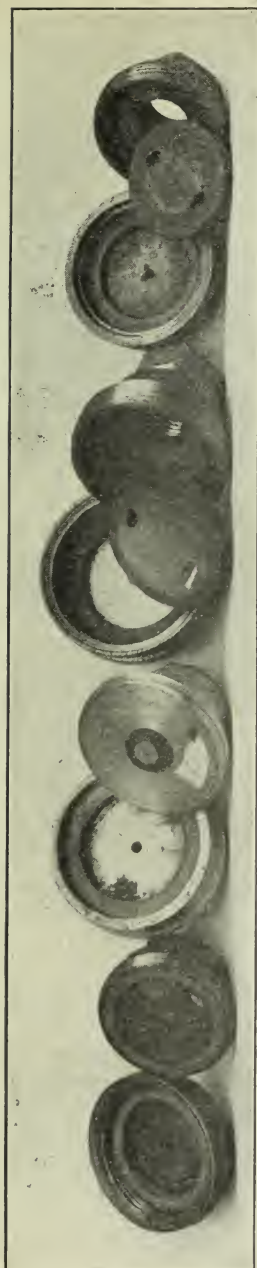
Agitators. Agitators are a frequent source of trouble in spraying outfits, especially in power machines. Swinging paddles usually pose as agitators or long rotary types are used in the bottoms of round tanks or barrels. These work very well in small tanks or barrels but are a decided failure in large tanks. The sliding agitator is the type used ordinarily in most power machines. Connections of the agitators to power are made in various ways but the principle is much the same

in different makes. The amount of power required to operate such an agitator is enormous, in proportion to the agitation one gets in an ordinary tank. Propellor agitators are much more efficient than other types because of the higher speed at which they may be run, their durability, simplicity, light weight, small size, and neat appearance, all being in their favor; besides possessing these qualities, they agitate the spray liquid thoroughly and require less power to operate them than any of the large, sliding types of equal efficiency. Jet agitators are often used on small hand pumps, but they are always inefficient and give very little agitation. A jet agitator, properly constructed would give fair agitation, but I know of none which utilizes the shape of the tank in helping to agitate the solution.

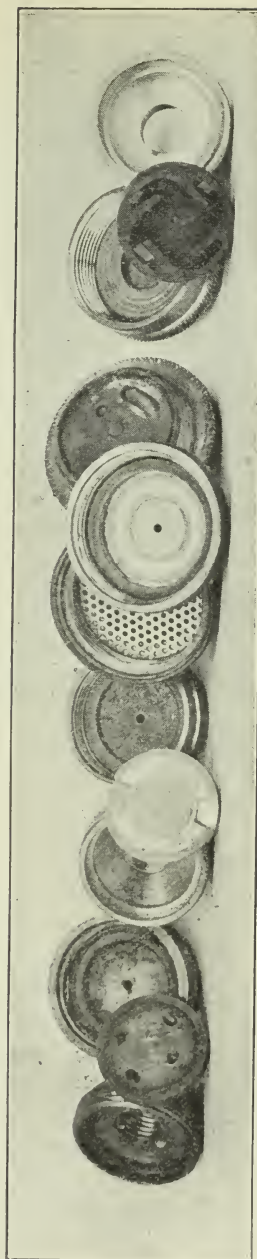
A number of hand-pumps are patterned after the ordinary water force-pump. With these the stuffing box is the source of so much friction that barrel pumps of this type should be avoided. Simpler types of pumps, without a stuffing box, should be selected. Plungers with a plunger-cup, or inside plunger-packing, require less power to operate them. Outside plunger-packing, or a stuffing-box on the outside of the plunger, is another method used in order to facilitate packing and obviate trouble. Double-acting pumps must necessarily have the stuffing box and plunger-packing too, but some of the strongest and most durable power pumps are of this type. Of the two latter types I have no particular choice, as each has its merits, and each requires about the same amount of care. The simple, single-acting pump with a plunger-cup or plunger-packing on the outside or inside, requires less attention than any of the other types and is preferable to the other types.

Supply tanks. Supply tanks are of various shapes and sizes, but the round-bottom tank is most used because it is easy to build and easily kept tight by merely tightening a few nuts on the clamp-rods. Hoop tanks always dry out and give trouble. Square, rodded tanks are very good but require more tightening of rods when they become leaky. They have some points of superiority in case the ordinary types of agitators are used, since these will agitate the solution better when it is driven into the corners of a square tank.

Nozzles. Nozzles are often a source of considerable trouble to the operator of a spraying outfit. Bordeaux nozzles throw an uneven flat spray, which is too coarse for most spraying. Vermorel types with medium caps throw a narrow-angle, fine spray, but they are of small capacity, are always catching on limbs and frequently clogging. Pressure at the nozzle-cap is also much reduced by the narrow orifices and tortuous channels through which the liquid must pass. Nozzles utilizing the principle of the whirl caused by the liquid entering from the sides of the whirling chamber, do not reduce so much the pressure



Spramotor Co's. Large Type. Friend Mfg. Co's. Aluminum Large Type. Hardie Mfg. Co's. Large Type. Goulds Mistry Jr.



Goulds Mistry Jr. Four-Hole. Winkle Nozzle. E C. Brown & Co's. Atoma Nozzle. Bean Spray Pump Co's. Large Type. NOZZLES

and force, and give a broader, finer spray, without reducing the speed of the liquid as it passes through the nozzle cap. They also allow the use of much larger orifices and abolish the trouble of nozzles catching on limbs. This brings us to the large types, which are made by a number of the companies and, so far as I know, all of these types of large nozzles are good.

FACTORS WHICH TEND TO MAKE A NOZZLE THROW AN EVEN SPRAY

One fault that manufacturers seem to have overlooked is the tendency of the large type nozzle to throw the bulk of the spray in one quarter of the circle. This may be overcome by making more supply holes through the plate or top of the nozzle under the whirling chamber. Nozzles with four holes through the plate, instead of two, throw an almost perfectly even circle of spray. These holes make the supply of liquid come from four quadrants instead of from one or two quadrants, and even up the spray passing out through the nozzle cap. The illustration of large nozzles shows one with a four-hole supply and another with four jetties around the holes and on the sides of the whirling-chamber which give the whirl to the liquid and make a fine, even spray, especially with the high pressure obtained from power outfits. Large-type nozzles are made by the following companies:

American Sprayer Co., Minneapolis, Minn.

Bean Spray Pump Co., Berea, Ohio.

E. C. Brown Co., Rochester, New York.

Deming Co., Salem, Ohio.

Field Force Pump Co., Elmira, New York,

Friend Mfg. Co., Gasport, New York.

Goulds Mfg. Co., Seneca Falls, New York.

Hardie Mfg. Co., Hudson, Mich.

F. E. Myers & Bro.: Ashland, Ohio.

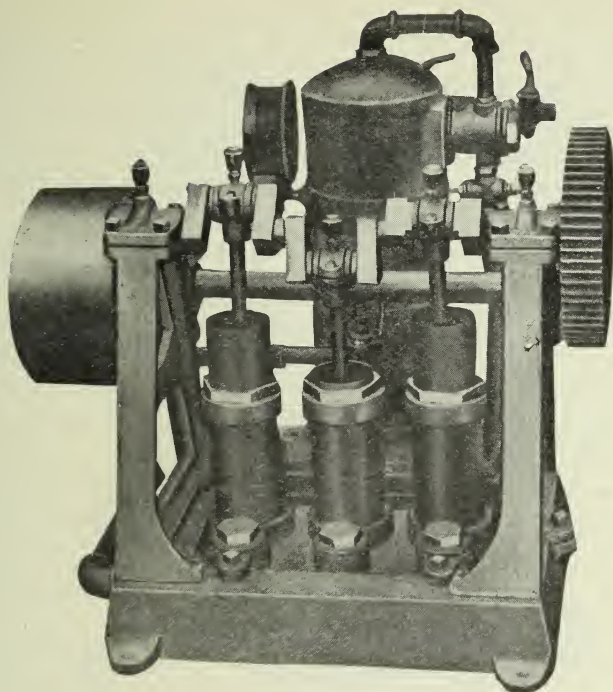
Spramotor Co., Buffalo, N. Y.

Wm. Stahl Sprayer Co., Quincy, Ill.

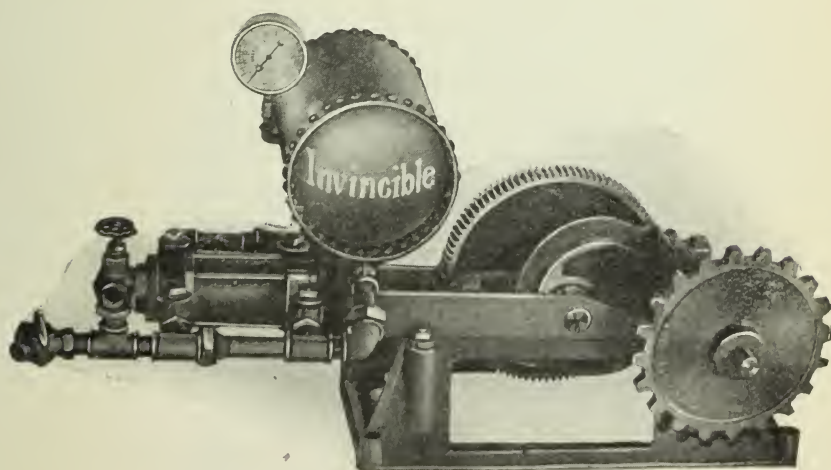
Geo. J. Winkle, Seneca Falls, New York.

Niagara Sprayer Co., Middleport, New York.

On an ordinary power outfit, two leads of hose should be used, a larger number seldom being of any great advantage in orchard work. The lead of hose to the man in the tower need be only fifteen feet long, while the man on the ground should have at least thirty feet, and forty feet of hose is not too much when spraying large trees. On hand- or barrel-pumps one lead of twenty-five or thirty feet in length does very well for all spraying work, or two leads of that length may be used when two men are on the ground.

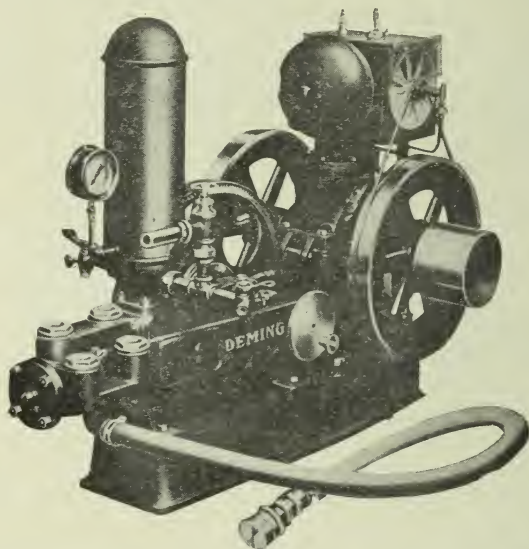


A pump which may be used with any engine of sufficient horse-power.
Hardie Mfg. Co.

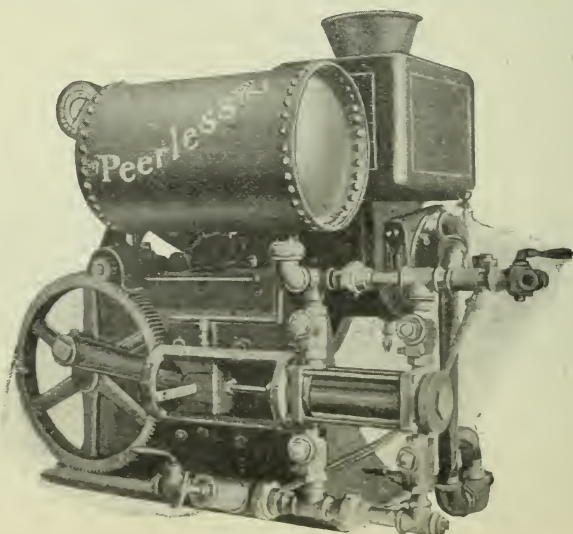


An independent pump that can be attached to any engine, belt-drive preferable.
American Sprayer Co.

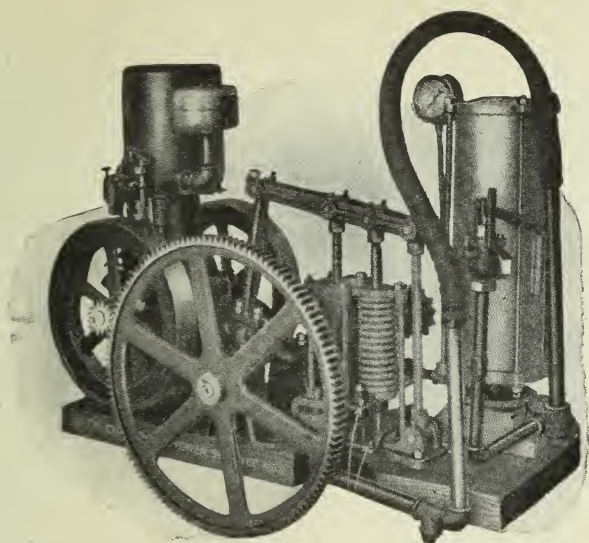
High pressure hose with long hose couplings and good hose bands are a necessity in spraying, for ordinary hose bursts under the high pressure to which it is subjected and short couplings are always making trouble. Half-inch high-pressure hose is most used, but three-eighths inch is also good and is not so heavy. The latter is harder to get connections for, when they are lost or broken, and may prove a little small in capacity when one uses three large-type nozzles on the end of a spray-rod.



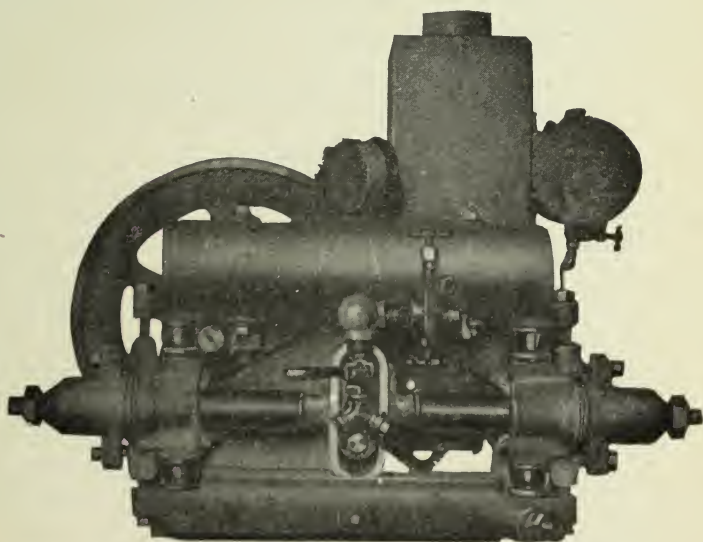
Deming double acting power pump with cast base and brass working parts.



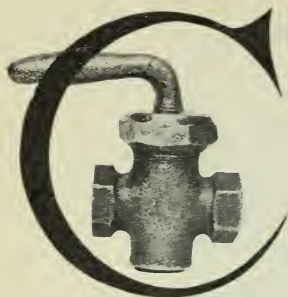
American Sprayer Co's. double-acting power pump with rod-clamped brass cylinder and brass working parts.



Bean power pump with one large diameter, single acting, porcelain lined cylinder and a patented spring attachment.

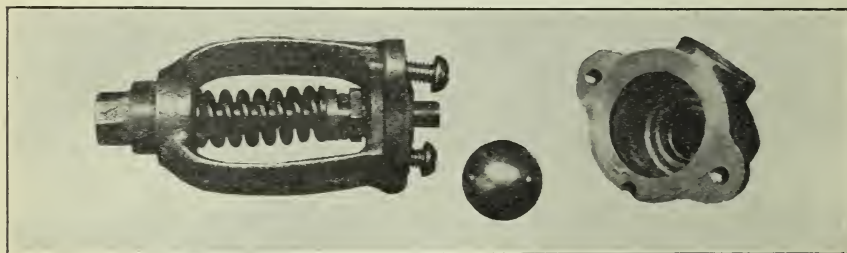


Friend power pump with two single-acting cylinders of small diameter.

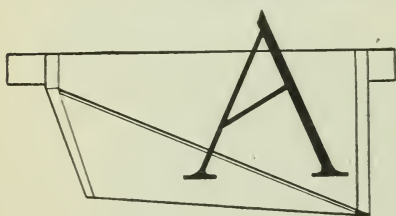


UT-OFFS between hose and rods are of many kinds and are more often too small than too large. They are troublesome to turn when too small and soon become leaky. The box type cut-off illustrated at the beginning of this paragraph is among the best.

Rods are made of iron pipe, brass pipe, and bamboo with a brass or aluminum tube running through the hollow bamboo. Aluminum-lined bamboo rods are lighter than any of the others and when properly reinforced at the ends are as strong as any bamboo rod put out. In length the rods should not be less than eight feet. Ten-foot rods are preferable and twelve-foot rods are often a necessity in order to reach the tops of high trees. Longer rods are not often needed, and are cumbersome and hard to handle on account of their length.



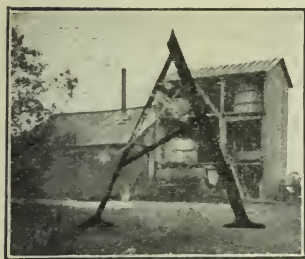
Hardie escape valve showing compressor, spring, ball, and seat. A neat, reliable and durable type of safety relief valve.



N excellent strainer can be made by fastening a piece of fine mesh brass screening in the frame of a box and at an angle of about 30 degrees, as shown in the illustration of the initial letter of this paragraph. One

end is sloped in so that the strainer may be lifted out by the end without sticking in the opening of the tank. The sloping screen is kept free from material through the action of the liquid, which is poured on the upper end of the screen and carries the material that will not pass through to the lower end. This keeps the screen clear for straining the liquid as it comes from the supply tank. This strainer may be made double by placing another similar one above the first, but with the screen sloping in an opposite direction. This is one of the simplest, most durable and efficient types of strainers, which can be easily made and repaired.

One of the necessities of the spraying business is a *good strainer*.



MOST important thing is a good, convenient mixing plant. I have not seen a half dozen good mixing-plants in northern Ohio. A good supply of water is needed. Two small sloping-end tanks for slaking lime should be set on an elevated platform high enough so that the lime will run into the mixing tank. The mixing tank should be large enough to hold almost

a sprayer-tank full. The tank for copper sulphate or blue vitriol solution should be on the same platform and preferably at the same height as the lime tanks. It should be of known capacity, so that a stock solution may be readily made up. All supply tanks should be higher than the top of the sprayer tank in order to run the mixtures into it readily. The platform around the tanks should be large so that the workmen can work on at least two sides of the tank. Only the side next to the sprayer need be left off, as long lengths of hose, pipe, etc., are not then needed to reach the sprayer. Valves or cut-offs can be omitted if sections of large-diameter hose are used, and when not in use the open end of the hose may be hooked up a little higher than the top of the supply-tank. This does away with the trouble of cut-offs clogging and being eaten out by the Bordeaux, an almost certain sequence, unless they are made of brass.

When a fruit grower intends to do much spraying he should always build a mixing-plant in order to facilitate the work. The saving of time and extra labor will pay for the mixing plant in a few seasons.

ACCESSORIES

Accessories to be considered when purchasing a spray pump:

High-pressure hose.	Suction hose.
Long hose-couplings.	Pressure gauge.
Hose-bands.	Nozzles.
Bamboo extension-rods (brass or aluminum lined) or pipe extension rods.	Drip guards.
Cut-offs (between rods and hose) preferably of the box type.	Y's and angle-elbows for nozzles.
Three-way cut-offs.	Strainers.
	Hose-reducers.
	A mixing plant.
	Escape valve.

COST OF SPRAYING

The cost of labor for a single spraying, basing the price at \$1.50 per day for a man, 75 cents for a boy, and \$1.50 per day for a team, is given in a table following this paragraph. Higher wages will increase the cost proportionately. The cost per tree varies with the capacity of the machine, the size of the trees, convenience of mixing

plant and distance from orchard to filling station. As much time must be allowed for filling as for spraying out a tankful of solution, and often one must add twice as much time for filling and mixing as for emptying. These estimates are for labor only, and do not include the cost of spraying materials. For details concerning materials and methods of application see Bulletins 191 and 199 and Circular 95.

LARGE POWER OUTFITS

Capacity, 1200 to 1600 gallons per day.

Rated capacity, 7 to 11 gallons per minute at 200 pounds pressure.

Number of trees sprayed per day, 100 to 200, according to the size of the trees.

Three men and one team needed.

Actual cost of labor, 1 cent per minute for a 10-hour day.

Time used, 2 to 6 minutes per tree.

Cost per tree, 2 to 6 cents.

SMALL POWER OUTFITS

Capacity, 800 to 1100 gallons per day.

Rated capacity, 4 to 7 gallons per minute at 150 to 175 pounds pressure.

Number of trees sprayed, 60 to 120 per day.

Two men, one boy, one team.

Actual cost of labor, .875 cents per minute.

Average time per tree, 5 to 12 minutes.

Cost per tree, 4 to 11 cents.

LARGE HAND SPRAY PUMPS

Capacity, 600 to 800 gallons per day.

Rated capacity, 3 to 5 gallons per minute at 125 pounds pressure.

Number of trees sprayed, 40 to 80 per day.

Three men, one team.

Actual cost of labor, 1 cent per minute.

Average time per tree, 6 to 15 minutes.

Cost, 6 to 15 cents per tree.

LARGE BARREL PUMPS

Capacity, 400 to 700 gallons per day.

Rated capacity, 2 1-2 to 4 gallons per minute at 125 pounds pressure.

Number of trees sprayed, 25 to 50 per day.

Three men, one horse.

Actual cost of labor, .875 cents per minute.

Average time per tree, 10 to 20 minutes.

Cost per tree, 8 to 18 cents.

MEDIUM BARREL PUMPS

Capacity, 300 to 500 gallons per day.

Rated capacity, 1 1-2 to 2 1-2 gallons per minute at 125 pounds pressure.

Number of trees per day, 18 to 30.

Two men, one horse.

Actual cost of labor, .625 cents per minute.

Average time per tree, 18 to 36 minutes.

Cost per tree, 12 to 22 cents.

SMALL BARREL PUMPS

Capacity, 150 to 200 gallons per day.

Rated capacity, 1 to 1 3-4 gallons per minute at 125 pounds pressure.

Number of trees per day, 10 to 20.

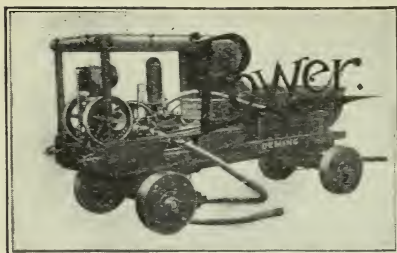
Two men, one horse.

Actual cost of labor, .625 cents per minute.

Time per tree, 25 to 45 minutes.

Cost, 14 to 28 cents per tree.

SPRAYING OUTFITS



SPRAYING outfits are briefly described in the following list:

American Sprayer Co. An orchard traction outfit of large capacity. Peerless outfit, two models of nearly same weight. Sliding agitator, Wallace water

cooled engine, 2 to 3 H.P. and double acting pump with swing check valves and a patent pressure regulator. Large air chamber, half round-bottom tank, fairly short-coupled trucks.

Invincible outfit, air cooled engine and Wallace Invincible pump. Other details similar to Peerless outfit.

Bean Spray Pump Co. The Challenge. A low, strong outfit of medium weight and large capacity, large porcelain lined cylinder, single acting pump with large bronze-ball valves. A type of propeller agitator, large air-chamber, water-cooled engine, 2 1-2 H.P. Short-coupled trucks, rectangular tank.

Deming Co. Premier outfit, large, very heavy and strong, of large capacity. New Way air-cooled engine, 2 1-2 or 3 1-2 H.P., sliding agitator, fairly long-coupled trucks, large air-chamber and double-acting pump with large ball valves. Half-round bottom tank.

Deming power outfit. Smaller and lighter than the Premier outfit but of large capacity. 1 1-2 H.P. water-cooled engine, pump, tank and trucks similar to the Premier outfit.

Cushman Power Sprayer Co. Three models, light outfits, medium and large capacity, Cushman water-cooled two cycle engine, 3 H.P. Duplex or triplex pumps, bronze ball valves, propeller agitator, round steel tanks, large wheeled, short coupled, strong trucks.

Olds Gas Power Co. Same as Deyo in most respects.

Goulds Mfg. Co. Like a Deyo outfit or a New Way outfit. Air-cooled engine 2 1-2 and 3 to 3 1-2 H.P. Goulds Vice Admiral pump, large air-chamber, wing-guided bevel-face poppet valves, sliding agitator, fairly short-coupled trucks, low and strong, half-round bottom tank.

Hardie Mfg. Co. Hardie Triplex, Light outfit, large capacity. Ideal water-cooled engine, 3 H.P., belted to Triplex pump. Ball-valves in pump, large air-chamber, half-round bottom tank, short-coupled trucks, sliding agitator.

Simplex outfit. Large and medium capacity, two sizes. Ideal water-cooled engine, 1 1-2 or 3 H.P., Simplex twin-cylinder pumps, similar to Triplex in other details.

Hardie No. 2. A light outfit, medium capacity. Ideal engine, 1 1-2 H.P., belted to pump-jack. Hardie pump, double-acting. It is without trucks and has a paddle agitator.

R. H. Deyo & Co. Deyo outfit. Heavy outfit of large capacity. Olds air-cooled engine, 2 1-2 to 3 H.P., Goulds Vice Admiral pump with large air-chamber, wing-guided bevel-faced poppet valves, sliding agitator, half-round bottom tank, fairly short-coupled trucks.

Fairbanks Morse Co. Very heavy outfit, large capacity, water-cooled engine.

Field Force Pump Co. Leader outfit, a heavy machine, large capacity, water-cooled engine, 3 1-2 H.P., sliding agitator, medium sized air-chamber, low, short-coupled trucks. Wheels with very broad tires. Half-round bottom tank.

Friend Mfg. Co. Friend regular model. Light outfit, large capacity. Friend air- or water-cooled engine, 2 1-2 to 3 1-2 H.P. New Friend pump, medium sized air-chamber, large ball-valves, half-round bottom tank, short-coupled trucks, large wheels with broad tires. Propellor agitator.

Friend Hilly Orchard. Similar excepting trucks, which have very large wheels in rear, with tank between them and small wheels in front which cut under and make an outfit which can be turned in a small area.

Spramotor Co. Light outfit, large capacity. Duplex pump, water-cooled engine, 1 1-2 H.P. Ideal engine, 2 1-2 H.P. or air-cooled engine. Sliding agitator, half-round bottom tank. Outfit has recently been revised and may be changed somewhat from the one described.

International Harvester Co. A heavy outfit of large capacity, with water-cooled engine and a double-acting pump.

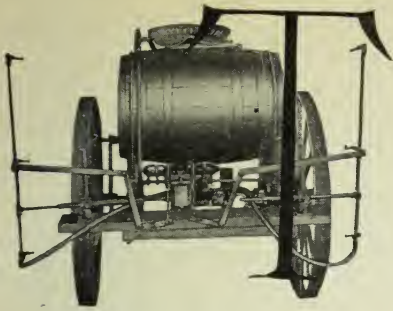
A lighter outfit of medium weight with an air-cooled engine, a double-acting pump, and a sliding agitator.

New Way Motor Co. A heavy outfit of large capacity. New Way air-cooled engine, Goulds, Deming or Myers double-acting pump. Half-round bottom tank, sliding agitator.

Binks Spraying Machine Co. Power outfit, medium weight. Water-cooled engine, double-acting pump. Sliding agitator, half-round bottom tank.

Power outfits should be chosen according to capacity and simplicity. Weight is a factor to be determined by the orchardist. His orchard may be hilly or level, and the size of trees and the kind of use a machine is to get will determine what sort of an outfit to purchase. Extremely light outfits, in most cases, are not as durable as the slightly heavier types. Weight and strength have been sacrificed for lightness, but the durability of such an outfit is in some few makes of machines nearly equal that of the heaviest types. Type of pump, valves, etc., also figure largely in durability, but most of the leading pump manufacturers use bronze-ball or bevel-faced wing-guided poppet valves, so this factor does not enter so largely in the choice of a pump. *Capacity, simplicity, efficiency, durability and cost*, are the factors one must consider. Choose preferably a close-coupled truck, with fairly large wheels in the rear and smaller wheels in front, all wheels with broad tires, and with the spraying machine frame set low, using the wagon without a bolster in the rear, if possible, but with the machine set level.

Home-made power outfits are not advisable, as very few have the facilities for connecting up pump and engine satisfactorily. Special purpose machines may be built at home, and also a good hand or independent power pump outfit may be readily assembled.

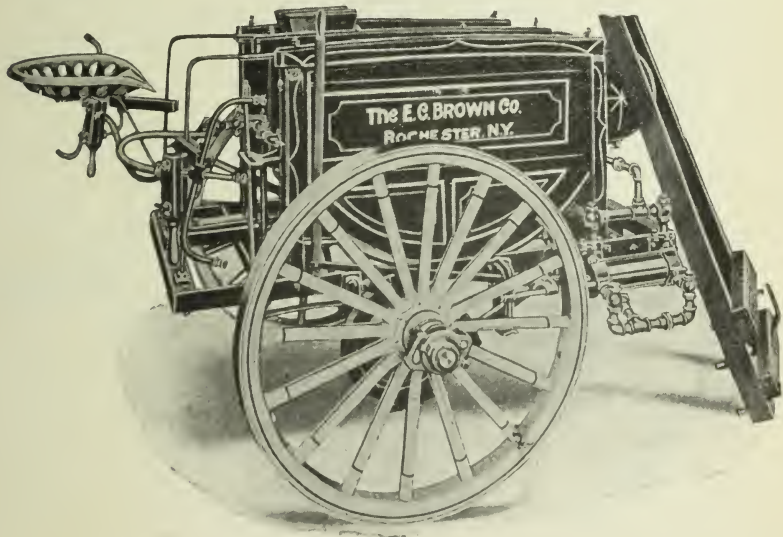


TRACTION-POWER sprayers are for the most part, special purpose machines. There are a few machines of this type built for orchard spraying but most of them were designed for spraying grapes, potatoes and similar field crops, or spraying for the destruction of weeds. Power is transmitted from the wheels by means of cams, eccentrics, chains or gears,

and the pump is operated by these various mechanical contrivances. Here, as in the case of other types, the same factors, *strength, simplicity, durability* and *capacity*, must be considered.

Traction machines were designed as special purpose machines, and are not a complete success for orchard spraying. Some few machines can be operated as hand pumps as well as used as traction machines.

For the man who has a small orchard and needs a field sprayer, some machine of this type should be selected; but the fruit grower who has a large orchard must look to the other types for a more suitable machine.



A traction sprayer with double-acting pump operated by an eccentric.

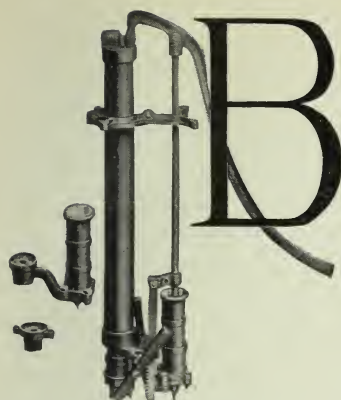


ARGE hand pumps approach small power-machines in capacity and are better than any barrel pumps on account of the long leverage that can be used. Two cylinders of smaller diameter are often used and the capacity is then greatly increased over that of the ordinary barrel pump. The entire weight of the body can be applied to the lever without stooping or bending the back, while any type of a tank or barrel can be used as the spray liquid container. For the man who cannot afford a power sprayer, or

who has a medium sized orchard and can get cheap labor, this style is very satisfactory.



A traction sprayer with a double-acting chain driven pump.



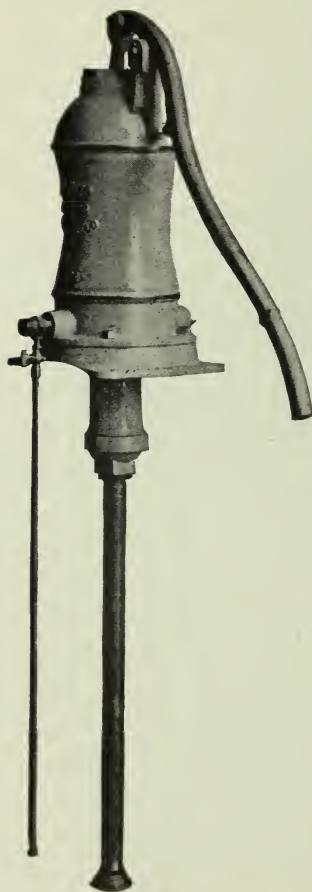
BARREL pumps of medium capacity are well suited to the small fruit grower or farmer who does not care to invest much money and yet wishes to raise good fruit. Medium capacity barrel pumps are to be preferred before the large capacity barrel pumps because the latter are hard to operate and it takes a heavy, strong man to pump one all day. Besides being useful for the man with a small home orchard, they may be successfully used for cold water painting, whitewashing, spraying chicken coops to destroy mites, lice, etc.



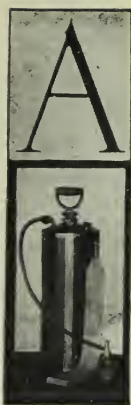
A barrel pump with valves, plunger and packing readily accessible.



BUCKET pumps were never designed for spraying the apple orchard, but they are convenient for spraying truck crops, small trees and bushes around the yard, chicken coops, and doing many other small jobs about the home, where a small convenient pump is needed. The Knapsack pump is a portable type of bucket pump, very useful for small work, and for spraying truck and garden crops.

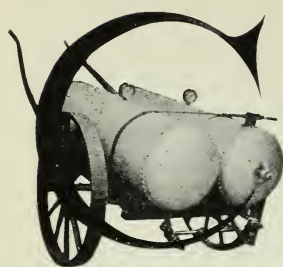


A barrel pump with plumbing connections and parts not readily accessible



AUTOMATIC sprayers are more convenient than knapsack sprayers, for they may be filled and then pumped up with air and the entire attention of the operator can be devoted to spraying without having to do the double duty of pumping and spraying at the same time. They are very convenient and readily carried about. For truck crops they are hard to beat when they are *well made*.

A fault of the larger part of the sprayers of this type is that they are made of galvanized iron and are corroded so rapidly by the Bordeaux sprays that they become worthless in a year or two. To be durable they must be constructed of heavy sheet brass, preferably seamless or with well riveted joints. For small work, a well made sprayer of this type is almost ideal.



COMPRESSED air sprayers have some advantages, since they are easily operated and are of very simple construction. For such outfits the first cost of the charging and mixing plant and of the sprayer tanks is somewhat greater than that of the average power outfit having an equivalent daily capacity, so far as the amount of liquid sprayed out is concerned. The pressure, when using a

compressed air sprayer, must vary between two extremes, usually from 160 to 80 pounds while the tankful of solution is being discharged. This tends to make the work uneven, since the quality of the spray varies from fine to coarse and there is also a variation in the amount of liquid discharged in a given time. On the other hand, power outfits are operated under an almost constant pressure which is often as great as 200 pounds to the square inch.

Considering these facts, and also that the amount of skilled labor required to operate either outfit is practically the same, I have reached the conclusion, after having operated both types of outfits in the field, that for the average orchardist, a power outfit is superior to the compressed air outfit.

In either case the operator must possess average mechanical ability and exercise reasonable care.

Sprayers using compressed gas have the disadvantage of decomposing the lime-sulfur sprays. For killing scale insects, lime-sulfur spray is one of the best, and is almost universally used in orchard work.

Dust sprayers have been successfully used in treating cotton, tobacco and a few similar field crops. In general orchard work they have not proved a success, as has been demonstrated in extensive competitive tests against liquid sprayers. However they have shown merit for such special use as dusting orange groves for rust mite. Their range of usefulness is evidently quite restricted.

In the following tables I have attempted to list the manufacturers who make various kinds of machines, so that an intending purchaser may write to those companies which build the kind of a machine he wishes to purchase, for catalogues and prices of the same.

Companies making Independent pumps to which power can be adapted:

American Sprayer Co., Minneapolis, Minn.
 Bean Spray Pump Co., Cleveland, Ohio.
 The Deming Co., Salem, Ohio.
 Field Force Pump Co., Elmira, N. Y.
 Goulds Mfg. Co., Seneca Falls, N. Y.
 Hardie Mfg. Co., Hudson, Mich.
 F. E. Myers & Bro., Ashland, Ohio.
 Spramotor Co., Buffalo, N. Y.

Companies manufacturing traction machines for grape, potato and field spraying, but sometimes adapted for use in orchards:

American Sprayer Co., Minneapolis, Minn.
 E. C. Brown Co., Rochester, N. Y.
 Dayton Supply Co., Dayton, Ohio.
 Field Force Pump Co., Elmira, N. Y.
 Goulds Mfg. Co., Seneca Falls, N. Y.
 Hardie Mfg. Co., Hudson, Mich.
 H. L. Hurst Mfg. Co., Canton, Ohio.
 Latham & Co., Sandusky, Ohio.
 Spramotor Co., Buffalo, N. Y.
 Wm. Stahl Sprayer Co., Quincy, Ill.

Companies manufacturing large capacity hand pumps:

Bean Spray Pump Co., Cleveland, Ohio.
 E. C. Brown Co., Rochester, N. Y.
 The Deming Co., Salem, Ohio.
 Field Force Pump Co., Elmira, N. Y.
 Friend Mfg. Co., Gasport, N. Y.
 Goulds Mfg. Co., Seneca Falls, N. Y.
 Hardie Mfg. Co., Hudson, Mich.
 F. E. Myers & Bro., Ashland, Ohio.
 Spramotor Co., Buffalo, N. Y.
 Wm. Stahl Sprayer Co., Quincy, Ill.

Companies manufacturing large capacity barrel pumps, the rated capacity of which is over two and one-half gallons per minute:

American Sprayer Co., Minneapolis, Minn.
 Field Force Pump Co., Elmira, N. Y.
 Goulds Mfg. Co., Seneca Falls, N. Y.
 Hardie Mfg. Co., Hudson, Mich.
 Latham & Co., Sandusky, Ohio.
 Morrill & Morley, Benton Harbor, Mich.
 Spramotor Co., Buffalo, N. Y.
 Wm. Stahl Sprayer Co., Quincy, Ill.

Companies manufacturing medium and small capacity barrel pumps.

American Sprayer Co., Minneapolis, Minn.
Barnes Mfg. Co., Mansfield, Ohio.
Bean Spray Pump Co., Cleveland, Ohio.
E. C. Brown Co., Rochester, N. Y.
Dayton Supply Co., Dayton, Ohio.
Deming Co., Salem, Ohio.
Field Force Pump Co., Elmira, N. Y.
Friend Mfg. Co., Gasport, Ohio.
Goulds Mfg. Co., Seneca Falls, N. Y.
Hardie Mfg. Co., Hudson, Mich.
H. L. Hurst Mfg. Co., Canton, Ohio.
Latham & Co., Sandusky, Ohio.
F. E. Myers & Bro., Ashland, Ohio.
Sramotor Co., Buffalo, N. Y.
Wm. Stahl Sprayer Co., Quincy, Ill.

Companies manufacturing Kerowater or Kerosene mixing sprayers:

Dayton Supply Co., Dayton, Ohio.
Deming Co., Salem, Ohio.
Goulds Mfg. Co., Seneca Falls, N. Y.
Sramotor Co., Buffalo, N. Y.

Companies manufacturing Knapsack sprayers:

Barnes Mfg. Co., Mansfield, Ohio.
Deming Co., Salem, Ohio.
Field Force Pump Co., Elmira, N. Y.
Goulds Mfg. Co., Seneca Falls, N. Y.
F. E. Myers & Bro., Ashland, Ohio.
Sramotor Co., Buffalo, N. Y.
Wm. Stahl Sprayer Co., Quincy, Ill.

Companies manufacturing bucket pumps:

American Sprayer Co., Minneapolis, Minn.
Barnes Mfg. Co., Mansfield, Ohio.
Bean Spray Pump Co., Cleveland, Ohio.
E. C. Brown Co., Rochester, N. Y.
Dayton Supply Co., Dayton, Ohio.
Deming Co., Salem, Ohio.
Field Force Pump Co., Elmira, N. Y.
Goulds Mfg. Co., Seneca Falls, N. Y.
Hardie Mfg. Co., Hudson, Mich.
H. L. Hurst Mfg. Co., Canton, Ohio.
F. E. Myers & Bro., Ashland, Ohio.
Wm. Stahl Sprayer Co., Quincy, Ill.

Companies manufacturing automatic sprayers:

American Sprayer Co., Minneapolis, Minn.
 Bean Spray Pump Co., Cleveland Ohio.
 E. C. Brown Co., Rochester, N. Y.
 Dayton Supply Co., Dayton, Ohio.
 Field Force Pump Co., Elmira, N. Y.
 Hardie Mfg. Co., Hudson, Mich.
 H. L. Hurst Mfg. Co., Canton, Ohio.

Companies manufacturing compressed air sprayers:

American Horticultural Distributing Co.,
 Martinsburg, W. Va.
 Latham & Co., Sandusky, Ohio.
 Niagara Sprayer Co., Middleport, N. Y.
 Pierce-Loop Co., Northeast, Pa.

Companies manufacturing dust sprayers:

Dust Sprayer Co., Kansas City, Mo.
 Leggett & Bros., New York, N. Y.

Companies assembling or manufacturing spraying machines:

American Sprayer Co., Minneapolis, Minn.
 Barnes Mfg. Co., Mansfield, Ohio.
 Bean Spray Pump Co., Cleveland, Ohio.
 Binks Spraying Machinery Co., Chicago, Ill.
 Cushman Power Sprayer Co., Lincoln, Neb.
 E. C. Brown Co., Rochester, N. Y.
 Dayton Supply Co., Dayton, Ohio.
 Deming Co., Salem Ohio.
 R. H. Deyo & Co., Binghamton, N. Y.
 W. & B. Douglas, Middleton, Pa.
 Fairbanks, Morse & Co., Cleveland, Ohio.
 Field Force Pump Co., Elmira, N. Y.
 Friend Mfg. Co.; Gasport, N. Y.
 Gilson Mfg. Co., Port Washington, Wis.
 The Goulds Mfg. Co., Seneca Falls, N. Y.
 The Hardie Mfg. Co., Hudson, Mich.
 Hurst Mfg. Co., Canton, Ohio.
 International Harvester Co., Local agencies.
 Latham & Co., Sandusky, Ohio.
 Morrill & Morley, Benton Harbor, Mich.
 F. E. Myers & Bro., Ashland, Ohio.
 The New Way Motor Co., Lansing, Mich.
 Niagara Spraying Co., Middleport, N. Y.
 Olds Gas Power Co., Lansing, Mich.

Pierce-Loop Co., Northeast, Pa.

Spramotor Co., Buffalo, N. Y.

Wm. Stahl Sprayer Co., Quincy, Ill.

In the following tables machines manufactured by the various companies are listed. The first column gives the name of the pump, the second, the kind of pump, the third, the capacity of the pump per minute, as the companies approved of or sent as correct at the pressure indicated in the fourth column, and the speeds given in the sixth column. The fifth column gives the estimates at the same speed and pressures as the companies capacities were given, but using the actual amount of liquid displaced per minute by the plunger. This does not allow for leaky valves, plunger-packing or jet agitators, so it is a little high in every case. Column seven gives the type of valves used in the pump; columns eight and nine, the length of stroke and diameter of the cylinders; column ten, the additional remarks upon the various types of pumps.

AMERICAN SPRAYER COMPANY

Name	Kind of machine	Companies capacities Gallons	Pressure Lbs.	Estimated capacities Gals.	Speed in strokes per minute	Type of valves	Length of stroke ins.	Diameter of cylind'r ins.	Remarks
Peerless	Power	8 to 11	200	8 to 12	50 strokes	Swing check	4	3	Double acting, rod clamped, brass cylinder with stuffing box.
Invincible	Indpt. power	7 to 9	200	7 to 9	250 feet per	"	3	3	"
Standard	Traction	20	125	18	"	"	8	3	"
Wallace Jr.	"	14	125	12	"	"	3	3	"
Wallace Field ..	"	15 1-2	125	13	"	"	4	4	"
Wallace Potato ..	"	10	125	9	"	"	3	3	"
Wallace Grape ..	"	10	125	9	"	"	3	3	"
Eureka No. 1	Barrel	1 to 1 1-4	125	1 to 1 3-4	30 strokes	"	4 4 1-2	2	Single acting, brass cylinder, inside plunger packed.
Eureka No. 5	"	2 to 2 1-2	125	2 to 2 1-2	"	"	4 1-2 5	2 1-2	"
Eureka No. 6	"	3 to 4	125	3 to 4	"	"	4 1-2 5	2 3-4	"

BARNES MANUFACTURING COMPANY

Name	Kind of machine	Companies capacities Gallons	Pressure Lbs.	Estimated capacities Gals.	Speed in strokes per minute	Type of valves	Length of stroke ins.	Diameter of cylind'r ins.	Remarks
Perfection	Bucket Barrel	1 1-2	50	1	30 strokes	Rubber ball	17	1	{ A double acting pump with brass cylinder and with a small reversed brass cylinder and plunger above doing away with a stuffing box
Double Acting	Barrel	1 1-2 to 2	125	1 1-2 to 2	"	Poppet	3 1-4	2 1-2	
New Improved	Bucket-barrel	2 to 2 1-2	125	2 to 2 1-2	"	"	4	2 1-2	
Perfection	"	1 to 1 1-4	125	1 to 1 1-4	"	Rubber ball	5 1-2	1 1-4	
Fig. 256	"	2 per	125	2 per	"	Bronze	12	1 1-4	

BEAN SPRAY PUMP COMPANY

Name	Kind of machine	Companies capacities Gallons	Pressure Lbs.	Estimated capacities Gals.	Speed in strokes per minute	Type of valves	Length of stroke ins.	Diameter of cylind'r ins.	Remarks
Challenge	Power	6 to 7	200	6 to 8	50 strokes	Bronze ball	4	3	Single acting, porcelain lined cylinder packing is a rubber composition cup.
Torrent	Indpt. power	10 to 11	200	10 to 12	30 strokes	"	4	3	
Magic No. 9	Hand	5 to 5 1-2	125	5 to 5 1-2	"	"	4	2 1-2	
Magic No. 10	"	3 to 4	125	3 to 4	"	"	4 1-2	3	
Nos. 7 and 6	"	2 to 3	125	2 to 3	"	"	4 1-2	2 1-2	
Junior No. 1	"	2 to 3	125	2 to 3	"	"	4	2 1-2	Single acting, porcelain lined cylinder packing is a rubber composition cup.
No. 70	Barrel	1 1-2 to 2	125	1 1-2 to 2	"	"	3 1-2	2 1-4	
No. 60	"	1 1-2 to 2	125	1 1-2 to 2	"	"	3 1-2	2 1-4	

E. C. BROWN COMPANY

Name	Kind	Companies capacity Gallons	Pressure Lbs.	Estimated capacity Gallons	Speed in strokes per minute	Type of valves	Length of stroke Ins.	Diameter of cylind'r Ins.	Remarks
Auto Spray No. 24	Barrel	1 1/2 to 2	125	1 1/2 to 2	30 strokes	Steam check	4	2 1/4	Outside packing, single action pump, plunger of hollow tube type, two cylinders, single acting, with packing on outside of plunger. All double acting stuffing box types of cylinders with cylinder tubes held in place by rods clamping on the cylinder heads.
" " 7	Hand	4 to 6	125	4 to 6	"	check	5	2 1/4	
" " 11	Traction	5 to 6	125	5 to 6	Calculated	valves in	6	2 1/4	
" " 15	"	5 to 6	125	5 to 6	that horse	all but	6	2 1/2	
" " 23	"	10 to 11	125	10 to 11	travels at	Auto Spray	6	2 1/2	
" " 27	"	5 to 6	125	5 to 6	250 feet per minute	30 and No.	6	2 1/2	
" " 28	"	10 to 11	125	10 to 11	under	2 Bucket,	6	2 1/2	
" " 29	"	10 to 11	125	10 to 11	which have	ball valves,	6	2 1/2	
" " 31	"	5 to 6	125	5 to 6	ordinary conditions.		6	2 1/2	
" " 32	"	10 to 11	125	10 to 11			6	2 1/2	
" " 33	"	10 to 11	125	10 to 11			6	2 1/2	

DAYTON SUPPLY COMPANY

Name	Kind	Companies capacity Gallons	Pressure Lbs.	Estimated capacity Gallons	Speed in strokes per minute	Type of valves	Length of stroke Ins.	Diameter of cylind'r Ins.	Remarks
Climax No. 1	Barrel	.9	125	.9	30 strokes	Poppet	5	1 1/4	Stuffing box, single acting valve in plunger types like well pumps
" " 2	"	1 1/6	125	1 1/6	"	"	5	1 1/2	
" " 3	"	2 to 2 1/4	125	2 to 2 1/4	"	"	5	2	
Destroyer	Traction	6 to 8	125	6 to 8	250 feet per minute for traction types	P & B check	5	2 1/2	
Dolphin	"	3 to 4	125	3 to 4		"	5	1	
Orchard	"		125						Double acting stuffing box, rod clamped cylinder types.
Economy	Bucket	1	125	1					

THE DEMING COMPANY

Name	Kind	Companies capacity Gallons	Pressure Lbs.	Estimated capacity Gallons	Speed in strokes per minute	Type of valves	Length of stroke Ins.	Diameter of cylind'r Ins.	Remarks
Premier	Power	7 to 10	200	8 to 9	50 strokes	Bronze ball	4	2 1/2	Stuffing box double acting type, with brass cylinder inside of cast iron frame. The Premier power and independent power are built with crossheads and guides. Canvas cups or rubber composition cups used on plungers. No stuffing box, small reversed plunger above. Similar to power pumps in construction.
Power	"	4 to 5	150	6 to 8	"	"	4 1/2	2 1/2	
Bonanza Power	"	7 to 9	200	4 to 5	"	"	3 1/2	2	
Indpt. Power	Indpt. power	7 to 10	200	8 to 9	"	"	4 1/2	2 1/2	
Sampson	Hand	3 to 5	125	3 to 5	30 strokes	"	3	2 1/2	
Bonanza 1	"	2 to 3	125	2 to 3	"	"	3 1/2	2	
Bonanza 2	"	4 to 5 1/2	125	4 to 5 1/2	"	"	4 1/2	2 1/2	
Century 1	Barrel	1 1/2 to 2	125	1 1/2 to 2	"	"	4 1/2	1 3/4	
Century 2	"	2 to 2 1/2	125	2 to 2 1/2	"	"	4 1/2	2 1/4	
Granger	"	1 1/2 to 2	125	1 1/2 to 2	"	"	4 1/2	2 1/4	
Simplex	"	2 to 2 1/2	125	2 to 2 1/2	"	"	4 1/2	1 3/4	Single acting, stuffing box type.
Captain	"	1 1/2 to 2	125	1 1/2 to 2	"	"	4 1/2	1 3/4	Single acting, inside plunger packing.
Gem Jr	"	3/4 to 1	125	3/4 to 1	"	"	4 1/2	1 1/2	Single acting, stuffing box type.
Bucket	Bucket	3/4 to 1	125	3/4 to 1	"	"	15	1	Single acting, stuffing box type.

FIFLD FORCE PUMP COMPANY

Name	Kind	Companies capacities Gallons	Pres-sure Lbs.	Estimated Gallons	Speed in strokes per minute	Type of valves	Length of stroke Ins.	Diam-eter of cylind-r Ins.	Remarks
Leader	Power	7 to 10	200	7 to 10	50 strokes	Poppet	5	2 1-2	Double acting pumps with stuffing box.
Ideal	Indpt. Power	8 to 12	200	9 to 12	"	"	5	3	"
Admiral	Hand	10 to 11	200	9 per	"	"	5	2 1-2	"
Empire Queen	Barrel	2 to 3	125	5 to 7	30 strokes	"	3 to 4	2 1-2	"
Empire King	"	3 to 6	125	1-4 to 2	"	"	3 to 4	2 1-2	Single acting pump with a stuffing box.
Jr. Empire King	"	2 1-2 to 5 1-2	125	2 to 3 1-4	"	"	3 to 4	2 1-2	"
Niakara Hydraulic	Hand	3 to 6	125	2 to 3 1-4	"	"	3 to 4	2 1-2	"
Victor	Traction	10 to 12	125	2 to 3 1-4	250 feet per	"	3	2 1-2	"
Wooster	"	5 to 8	125	4 to 5	"	"	3	2 1-2	"
Watson	"	6 to 10	125	5 to 6	"	"	3	2 1-2	"
Wild Rose	"	10 to 12	125	6 to 9	"	"	3	2 1-2	"
Arastook	"	10 to 12	125	6 to 9	"	"	3	2 1-2	"
Eagle	Barrel	3 to 6	125	2 to 3 1-4	30 strokes	"	4	2 1-2	Single acting pump without a stuffing box.

FRIEND MANUFACTURING COMPANY

Name	Kind	Companies capacities Gallons	Pres-sure Lbs.	Estimated Gallons	Speed in strokes per minute	Type of valves	Length of stroke Ins.	Diam-eter of cylind-r Ins.	Remarks
Friend	Power	7 to 8	200	7 to 8	50 strokes	Ball	3 1-2	2	Cylinder, outside plunger packed, single acting.
Friend Jr	Barrel	2	125	2	30 strokes	"	2	2	"

GOULDS MANUFACTURING COMPANY

Name	Kind	Companies capacities Gallons	Pres-sure Lbs.	Estimated Gallons	Speed in strokes per minute	Type of valves	Length of stroke Ins.	Diam-eter of cylind-r Ins.	Remarks
Triplex	Power	8 to 10	200	8 to 10	50 strokes	Bevel-faced wing-guided poppet valves.	3 1-2	2 1-2	The Admirals are double acting pumps, brass lined cylinders, with a stuffing box.
Vice Admiral	"	7 to 8	200	8 to 10	"	"	4 1-2	3	Emperor and Monarch have single acting double cylinders with outside plunger packing.
Emperor	"	6 to 8	200	4 to 6	"	"	4	2	"
Monarch	Hand	4 to 5	200	4 to 5	30 strokes	"	4	2 1-2	"
Pomona	Barrel	2 to 3 1-4	125	3	"	"	4	2	Barrel pumps are single acting and all are without stuffing boxes.
Savelot	"	2 to 3 1-4	125	2 to 3 1-4	"	"	3, 4 or 5	2 1-2	"
Fruitall	"	1-2 to 1 2-3	125	1-2 to 1 2-3	"	"	3, 4 or 5	2	"
Standard	"	2 1-4 to 3 1-4	125	2 to 2 1-2	"	"	3 1-2	2 1-2	"
Premier	Bucket	1	125	1	"	"	4 1-2	2 1-2	"
Admiral	Hand	5	125	5	"	"	4 1-2	3	"
Standard	Barrel	2 1-2 to 3 1-4	125	7	"	"	3 1-2	3	"

HARDIE MANUFACTURING COMPANY

Name	Kind	Capacities Gallons	Pressure Ins.	Estimated capacities Gallons	Speed in strokes per minute	Type of valve	Length of stroke Ins.	Diam- eter of cylinder Ins.	Remarks
Triplex	Power	5 to 8	200	5 to 7	50 to 80	Bronze ball	2 3-4	2	All power machines excepting No. 2 have outside plunger packing, single acting cylinder types. No. 2 double acting pump with cylinder threaded to receive the cylinder heads. Outside plunger packing, 2 single cylinders. Inside plunger packed, single acting pumps without a stuffing box.
Simplex C	"	7	200	7	50 strokes	"	3 1-2	2 1-2	
Simplex D	"	5 1-2	200	4 1-2	"	"	3 1-2	2	
No. 2	"	4 to 5	175	4 to 5	"	"	5	1 5-8	
Twin cylinder	Hand	3 to 3 1-2	125	3 to 3 1-2	30 strokes	"	3 1-2	2	
No. 4 1/2	Barrel	2-3	125	2-3	"	"	3 1-2	2	
No. 5	"	1 1-3	125	1 1-3	"	"	4	1 5-8	
No. 6	"	2	125	2	"	"	5	2	
No. 7	"	4	125	4	"	"	5	2 1-2	"
Bucket	Bucket	1-2	125	2-3	"	"	5	1 1-4	

H. L. HURST MANUFACTURING COMPANY

Fitzall	Barrel	1 1-2 to 1 3-4	125	1 1-2 to 1 3-4	30 strokes	Bronze ball	4 1-2	2 1-4	Single acting outside plunger, packed pumps.
Hurst	Traction	4 to 5	125	4 to 5	250 feet per	"	4	2 1-2	

LATHAM & COMPANY

Latham 3	Barrel	1 to 1 1-2	125	1 1-2 to 2	30 strokes	Poppet	3 to 5	2	Single acting without a stuffing box. A mique type.
" 4	"	2 to 2 1-2	125	2 to 3 1-4	"	"	3 to 5	2 1-2	

MORRILL & MORLEY

Barrel	Barrel	2 to 3	125	2 to 3	30 strokes	Poppet	3 to 4	3	Single acting, inside packed plunger.
--------------	--------	--------	-----	--------	------------	--------	--------	---	---------------------------------------

F. E. MYERS & BROTHER

Name	Kind	Companies capacity Gallons	Pressure Lbs.	Estimated capacity Gallons	Speed in strokes per minute	Type of valves	Length of stroke Ins.	Diameter of cylinder Ins.	Remarks
Pitman Power	Power	7 to 10 5 to 7	200 200 200	7 to 10 5 to 7	50 strokes " "	Poppet	5 5	2 1-2 2	Double acting pump with stuffing box and brass lined cylinder.
Back Geared Hydraulic	Hand	3 1-4 3 3	125 125 125	3 1-4 3 3	30 strokes " "	" "	4 1-2 5 4 1-2	2 2 1-2 2 1-2	These pumps are without a stuffing box and have a reversed plunger in the double-acting barrel pumps.
Double Acting	"	3 1-4 2 2	125 125 125	3 1-4 2 2	" "	" "	4 1-2 3 1-2 3 1-2	2 2 1-2 2 1-2	
O. K. Barrel	Barrel	2	125	2	" "	" "	3 1-2	2 1-2	
Perfect	Barrel	2	125	2	" "	Ball	3 1-2	2 1-2	

SPRAMOTOR COMPANY

Duplex Power	Power	6 to 8 4 to 5	200 125	6 to 8 4 to 5	50 strokes 30 strokes	Ball	6 6	2 2	All inside plunger packed, single acting pumps with no stuffing box and one or two brass cylinders.
Duplex	Hand	2 to 3 2 to 3	125 125	2 to 3 2 to 3	" "	" "	3 5-5.5 2	2 1-2 2	
Field and Grape	Traction	2 to 3 2 to 3	125 125	2 to 3 2 to 3	" "	" "	4 1-2 4 to 5	1 3-8 3	
Spraintner	Barrel	3 to 4 3 to 4	125 125	3 to 4 3 to 4	" "	" "	4 1-2 4.5-5.5	3 1-2 1 1-4	
Spramotor No. 1	"	4 to 6 1-2	125 125	4 to 6 1-2	" "	" "	3 1-2	1 1-4	
" " 2	"	4 to 6 1-2	125 125	4 to 6 1-2	" "	" "	3 1-2	1 1-4	
Knapsack	Knapsack	1-2	125	1-2	" "	" "	3 1-2	1 1-4	

Wm. STAHL SPRAYER COMPANY

Excelsior No. 27	Hand	4	125	3 1-2 to 4	30 strokes	Poppet	2 3-4 3 to 5	2 1-2 2 1-2	Double acting stuffing box type. Similar to Gould's barrel pumps in construction
" " 22	Barrel	2 to 3 1-1	125 125	2 to 3 1-1	" "	" "	3 to 5 3	2 1-2 2 1-2	
" " 23	"	2 to 3	126	1 1-2 to 2	" "	" "	3	2 1-2	

In conclusion let me set forth a *few things which should be remembered.*

1 Choose a machine that has the factors of *simplicity, durability* and *capacity* and the *efficiency* of the machine will be unquestioned.

2 Cost is another question. A few dollars higher in price usually means *better quality* and "the best is the cheapest in the end."

3 *Clean up your machine and accessories each time* when you are *through spraying.*

4 *Keep your machine in good trim, all bolts and bearings tight, plunger packed, etc.*

5 Use *good oil* and *plenty* of it.

6 If something goes wrong and fails to work *find out* what the *trouble* is, before you *change any adjustments.* *Changing adjustments* without knowing *why* only means *more trouble.*

7 *Results* depend upon *thorough work* and the *use* of *good standard brands* of spraying materials.

8 *Study your machine* and your *problem* and *persevere.*

ACKNOWLEDGEMENTS

To the spraying machinery companies for their kindness and assistance in furnishing parts of machines and illustrations for the illustrated lecture which led to the preparation of this bulletin; to the Station photographer, Mr. Wm. P. Beeching Jr., who prepared the designs for the illustration of this bulletin, and to all those who assisted in other ways, I wish to express my thanks.

BULLETIN

OF THE

Ohio Agricultural Experiment Station

NUMBER 217

MAY, 1910

APPLE CULTURE IN OHIO

By F. H. BALLOU

APPLE GROWING IN OHIO—PAST, PRESENT, PROSPECTIVE

We may divide the history of apple growing in Ohio into three epochs: First, the period of abundance and encouragement; second, the period of adversity and perplexity; third, the period of awakening and restoration. The first period is past; we are emerging from the dark, dispiriting years of the second into the cheering dawn of the third—a period of general reconstruction, upon a broad and substantial basis, of an industry that will not only endure, but will, through aid of modern scientific methods, perform its part in winning for Ohio fame as a horticultural state whose heritage embraces every requisite, natural resource.

It is well for us to give thought, in a practical, common-sense way, to a situation so fraught with interesting facts and wholesome lessons as the history of apple culture in Ohio. What a familiar story it is—of the early years when the virgin soil of plain, hill and dale brought forth fruit in generous abundance; when glowing, golden and ruby apples in unblemished perfection bent in rainbow curves the strong branches of healthy trees whose foliage was of deepest green; when little effort was rewarded with great returns; when the substantial income of welcome dollars, gained through the sale of surplus fruit rendered the new-born industry of considerable importance in various sections of Ohio; when no thought seemed necessary to be devoted to the future physical needs of the trees nor to the possibility of grave problems arising where the “balance of nature” had been disturbed by so radical a measure as

removing large areas of native vegetation and planting special crops. These, indeed, were the years of revelation—years abounding in clearly demonstrated lessons relative to the resources of the new country and the innate power of youthful Ohio's soil and climate, unhampered by adverse, superficial influences, to produce beautiful, sound, perfect fruits.[†]

Then gradually came the shadows of the period of perplexity and discouragement—the years which brought with them trial of human faith and resource; years in which the scientist was untiring and hopeful in experiment and research, and a few undaunted, wide-a-wake orchardists alert and attentive, faithfully keeping abreast with scientific progress; years in which unobservant, indifferent, faint-hearted orchard owners were puzzled or skeptical. The advent of this period of confusion had its origin in the stealthy appearance of insect foes infesting the foliage and fruits of the apple, and which multiplied and spread until the destruction wrought was state-wide and alarming in intensity. No less a scourge became the various fungous and bacterial diseases which later appeared and became so disastrously prevalent, sweeping through the orchards of hill and vale and spreading their blighting, gnarling infection throughout Ohio. The once beautiful and prolific orchards, in numberless instances, came to be regarded as problematical incumbrances of the ground rather than profitable adjuncts of the farm as in the early years. As a result of the discouragement occasioned by serious insect and fungous parasitism, owners quite generally subjected their orchards to the additional afflictions of starvation, thirst, exposure to extremes of cold and heat and mutilation by pasturing live stock, unmodified by any system of culture that would tend to maintain fertility, conserve moisture, afford protection from extremes of temperature or the vicissitudes of the pasture-lot, meadow or corn-field into which such orchards were quite commonly converted. Thus is the closing of the period of mysterious affliction; of wonderment and gloom; of discouragement and complaint. Has discouragement been justified, and complaint well founded?

And now the dawn of awakening is upon us. The faithful orchardist, throughout the period of trial, kept his eye steadfastly upon scientific progress made in combating the enemies and obstacles in the way of successful orchard management, and applied the lessons as they became available. He succeeded financially throughout the period of depression—producing choice fruit and obtaining high prices even when the shadows of adversity were darkest over his less progressive neighbors' orchards. He has

become a leader and a missionary in his neighborhood. The truth, moreover, now becomes clearly apparent that those same enemies and obstacles—the various insect pests, fungous diseases, and waning vigor of uncultivated, unfed, unpruned orchards—actually constituted a blessing in disguise. Had the days of universal, abundant, unrestricted fruitage continued as in the early period of orchard planting, when no special effort need be put forth in order to insure rich harvests, there would today be no premium fixed upon superior, individual intelligence, progressiveness and industry. The careless and indolent person would gather from his land rewards equal to those of his wide-a-woke, industrious neighbor who studies to win and toils to produce a superior product and to place it upon the market in attractive form. Such condition, indeed, would render impossible the developement or continuity of such an institution as an appreciative, discriminating, merit-rewarding public market.

Therefore let us reassure and fortify ourselves with this simple, fundamental truth, that a wise and considerate Providence purposely exhibited to us during an early and ample period of time that is now gone forever, the wonderful possibilities of our great state in the production of beautiful, luscious apples and other fruits, unrestricted by the limiting factors which were to come. Not by any means, nor for a single moment should we entertain the belief that such a marvellous object-lesson came by chance. God simply revealed to us, through the medium of nature, the power of our soil and the suitability of our climate to produce fine, perfect fruit when the necessary conditions were met, that those who might observe would give serious thought to these possibilities, and that in the future they might be encouraged and determined to intelligently combat and subdue when restrictive enemies and barriers to success should appear.

The ample period of that clear-cut, practical revelation has passed. Scientific study and experiment by earnest, thoughtful men have developed, and are still perfecting, methods of control of the numerous insect foes and fungous diseases which have come in the course of time to render more profitable the earnest endeavor of the faithful horticulturist, and to eliminate from competition the thoughtless, careless negligent orchard owner.

There is, indeed, a great awakening. Help is being sought in various parts of our state. The sentiment is growing—and with substantial foundation—that we have within the boundaries of our own good state “a land of big, red apples” second to none in this or any other country. We are, therefore, in the midst of an active

educational campaign in which our state institutions—educational and experimental—are laboring “shoulder to shoulder.” There is but one recognized goal for the future: That Ohio shall take her rightful place among the leading apple growing states of our Union. Which means that there shall be a development of the latent resources not only of hundreds of our hitherto discouraged land owners, but of thousands of acres of our idle lands in the rougher portions of Ohio.

THE ESSENTIALS OF SUCCESSFUL APPLE CULTURE

Apple culture of the present day depends upon a number of factors each of which determines, to a greater or lesser extent, the degree of success which may be attained. The principal points to be taken into consideration by the prospective planter or purchaser of an orchard may be named as follows: Location, elevation, soil, varieties, planting, culture, pruning, spraying and thinning. The greatest determining factors of all, however, are the personal qualities of the orchardist himself. The man who is fitted by nature, inclination and more or less thoughtful, careful preparation for horticultural work, will succeed under somewhat adverse conditions, while his neighbor in whom there is tendency toward thoughtless, careless habits and lack of interest will fail even under much more favorable environment.

Location of the orchard

It is a great advantage if an orchard situation may be within convenient reach of a good shipping point. Ohio is especially well provided with a great system of railroads, one or more lines of which reach every county of the state. The extension of interurban electric railroads has also done much to multiply desirable orchard sites. The border counties of eastern and southern Ohio possess excellent facilities for river transportation which is now assured of substantial improvement from year to year. Greater still is the advantage if an orchard be situated within driving distance of one of the many thriving cities of Ohio. For the smaller orchardist, especially, a good home market is found in every city and village of the state; moreover, many farmers prefer to devote their attention wholly to their own specialties and buy fruit rather than to grow it. There are many thousands of acres of idle lands in Ohio, unsuited to agricultural purposes, lying adjacent to great railway lines, which are admirably situated for extensive orchard work, and the time is coming when all these vast areas of idle lands will be required to perform a part in producing the food supply of our rapidly increasing population.



A southern Ohio railroad which passes through a country abounding in excellent sites for commercial apple orchards. Tens of thousands of acres of idle land lie along the right-of-way of this and other southern Ohio railroads

Elevation While apples may be grown with some success in level sections of the state, it is a very great advantage if the site chosen for the orchard be somewhat higher than the land adjacent. An elevation of even a few feet above the channels or beds of local streams of water will provide not only the necessary water drainage, but also favor frost or cold air drainage which is of almost equal importance. It is a generally well known fact that, under weather conditions which favor frost, the colder atmosphere being the heavier seeks the lower levels of the valleys, ravines and depressions, while the warmer, lighter air envelopes the slopes and summits of the higher ground, often entirely preventing injury by frost in late spring, to the blossoms or young fruit. This is especially true of those areas of our state remote from the larger bodies or streams of water. The modifying and retarding influences of Lake Erie upon temperature, as affecting vegetation, renders a large area of adjacent, level land well protected from extremes of temperature. (See Circular No. 94, pp. 9-10). In the valleys of our larger rivers, such as the Ohio, Muskingum and others flowing through the rougher parts of the state and bordered along their courses by high hills on either side, it sometimes occurs, during extremely frosty weather, that the dense

river fogs protect the lower levels from frost while vegetation on the higher altitudes suffers severely. For this reason there may be exceptions made in favor of orchard sites on the more elevated portions of "second bottom" land of some of the greater river valleys, as that of the Ohio; but this will not generally apply to the much smaller valleys of the lesser tributaries. Excessive humidity, in the valleys of the great streams of water, favors the development of certain forms of fungi affecting the apple—such as the "sooty blotch" or fungus—which are rarely troublesome on the more elevated sites. As a rule, the preference of location for an apple orchard would wisely be given to the elevated hill-slope or summit.

Soil Admitting the truth that apples are being successfully grown, in some parts of Ohio, on soil so poor that it would not produce 10 bushels of corn per acre, it is at the same time true that in order to secure healthy, vigorous, well-grown trees, which will devote a long life to generous fruit-bearing, there must be in the soil those elements which constitute fertility and good physical character. These elements, of which there are three more important, are both mineral and vegetable. Potassium and phosphorus are of mineral origin, while nitrogen is derived from the growth, breaking down and decay of vegetation—especially that class of plants belonging to the family of legumes—the clovers, peas, vetches, etc. (Bulletin No. 171, pp. 191-192).

Abundant decayed and decaying vegetable matter, within or upon the surface of the soil, is very desirable aside from the direct bearing it will have upon the nitrogen supply. A soil filled or covered with humus or vegetable fiber readily absorbs and retains a vastly greater amount of water than a soil depleted of its humus by frequent and injudicious cropping or cultivation. The humus also acts as an effective medium of insulation against extremes of cold and heat.

Culture There are two methods of orchard culture that may be safely practiced in Ohio, which will build up and maintain the necessary supply of vegetable matter in the soil. These are: first, cover-crop culture; second, mulching.

Cover-crop culture consists in annually plowing or disking the orchard area as early in the spring as the ground can be readily worked, followed by a short season of cultivation which may be done with a harrow or fine-toothed cultivator. In June cow peas or soy beans are either drilled in at the rate of three pecks or sown broad-

cast at a bushel and a half per acre, and allowed to grow, ripen and remain upon the ground over winter, to be disked or plowed under the following spring, after which the same plan is to be followed as the year preceding. An excellent plan is to drill the peas or beans with a common grain drill, stopping all but every third opening which is left wide open. This gives spaces of two feet between rows and admits of two or three very beneficial cultivations of the young plants, with a fine-toothed cultivator. Cow peas do excellently in southern Ohio, but the soy beans seem better adapted to the northern half of the state. Rye may be sown broadcast among the beans or peas in September, and lightly cultivated in. This will provide a living, winter cover-crop and an additional heavy growth of vegetation to turn under the following spring. The rye is usually permitted to grow in spring until it is nearly ready to head, before plowing under. This method of culture rapidly builds up the soil in humus content and is adapted to level or comparatively level land that can be cultivated repeatedly without loss of soil by washing. Crops of corn or potatoes may be grown in the orchard during its early years, but the ground should be manured each season or some cover-crop plowed under, in order not to deplete the soil of humus, as it will be found to be difficult to get any crop whatever to grow in the orchard after the trees reach considerable size.

The mulch method of culture consists in maintaining the orchard area in grass—the thicker and heavier the better—and heavily mulching about the trees, either with the grass which grows between them or with material of similar nature hauled in from elsewhere. The grass in the orchard is cut in June, for the first time of the season, and, if the crop be sufficiently heavy, is raked, divided and thrown under the trees in a circle a little farther out than the tips of the branches extend. If the crop of grass be light it is as well to leave it upon the ground where it falls when cut, and depend upon material from outside sources with which to mulch the trees. Straw, old hay, swamp grass, broom sedge, weeds, potato vines, cornstalks or any kind of coarse, vegetable matter may thus be profitably used. This mulch, to the depth of from four to six inches, should be maintained under the outer ends of the branches of the trees by annual or biennial applications. It not only holds the rainfall and conserves the moisture in the soil, but it keeps the ground over the root systems cool in summer, prevents freezing deeply in the winter and affords, by its gradual decay, an abundant supply of plant food for the trees.

Mulched apple trees make fully as vigorous growth, bear earlier and produce fruit of firmer texture and higher color than trees under the cover-crop method. The mulch method is especially

adapted to the rough, hilly areas of our state, where serious washing of the ground would occur under any system involving frequent plowing and cultivation. (See Bul. 171 for fuller discussion of orchard culture.)

Planting It may be well, in connection with the subject of orchard culture, to touch briefly upon the planting of young apple trees. The distance apart at which to space the trees should be governed largely by the character of the soil upon which the orchard is to be located. Where the soil is thin, as in many of the hilly sections of Ohio, 25x25 feet apart is a good distance. On richer ground the distance should be not less than 35x35 feet either way, or the equivalent. Some growers plant 25x30, while still others who have had experience with apple orchards on very fertile soil recommend not less space than 40 feet between trees either way.

If it be possible to do so it is an excellent plan for the planter to visit the nursery and see the stock before buying. If there be a nearby nursery, so much the better. Well grown trees, true to name, produced near home are as good in every way as those from more distant points—no matter what direction. Indeed it is what a tree really is and not where nor by what method it is grown, that should be the determining factor of the purchase. Budded and root-grafted trees are equally good and desirable if they are equally well grown and vigorous. It is also a good plan to purchase the trees in the autumn and heel them in where they will be secure from mice or other rodents, so that they may be at hand for planting just as soon in the spring as the ground can be worked. Or they may be safely planted in the autumn, if the work be well done. Fall planted trees should have a generous mound of soil thrown about their bases. The plan of planting peach trees in an apple orchard is not to be commended, unless the apple trees are set at wide distances apart, and then the peach trees should be set in the centers of the squares only. Apple trees, of upright growing varieties, may be more safely used as fillers than peach trees, but, as a rule, the best apple orchards are grown without fillers.

If cover crop culture be the system contemplated, the ground for the young orchard should be plowed and well prepared as for any farm crop. After carefully marking off the rows the trees are planted at the proper intersections, in holes large and deep enough to nicely accommodate the roots without bending or crowding together. If the mulch system is to be followed the ground should be carefully staked off and the holes for the trees dug in the sod, making them fully $2\frac{1}{2}$ feet in diameter and 14 to 16 inches in depth,

throwing the fine, top soil to one side and the coarser subsoil to the other. The preparation of the young tree is the same in either method of planting. The rough, mutilated ends of the larger roots should be smoothly cut off with a sharp knife, and broken roots removed entirely. As is always the case in digging the trees from the nursery rows, a large part of the root system is left in the ground; therefore the tops of the young trees should be cut back severely to balance the loss of roots. Select four or five branches, so situated as to promise a well-balanced, symmetrical head, smoothly cutting all others away. The branches selected should then be cut back to from 4 to 6 strong buds.

Well grown, low-headed, two-year-old-trees are usually most satisfactory for planting, and should be set an inch or two deeper than they stood in the nursery row. In planting the trees, use the fine, top soil among and about the roots, firming well with the feet. The coarser soil is thrown upon this and left lying loosely.

If the orchard is to be tilled, cultivation should begin at once after planting. If the mulch method is the plan adopted a space three or four feet in diameter, about each tree, is at once heavily mulched with strawy manure, straw or other similar material at hand. In early autumn draw the mulch back from about the base of the tree and throw a half dozen shovelfuls of soil or cinders close up about the stem, forming a compact little mound. This precaution against the work of ground mice should be repeated each autumn—pounding down the old mound with a post tamper and adding a few more shovelfuls of soil or cinders. If there be danger from rabbits, the stems of the trees may be wrapped for the winter in building paper, or fine-meshed wire screens may be used against both mice and rabbits. (See Bul. 208).

The following brief lists of varieties contain the names of apples which may be planted with confidence in Ohio. The varieties are named nearly in the order of their seasons of ripening—from the earliest to the latest: Those with a * are the best for market.

FOR NORTHERN OHIO

*Yellow Transparent, *Duchess, Tetofsky, Early Harvest, Liveland Raspberry, *Maiden Blush, *Wealthy, *Grimes Golden, *Jonathan, H. Hubbardston, Red Canada, *Baltimore, *Baldwin, *Gano, *Stark, *Sutcliffe, Spy, R. I. Greening.

FOR SOUTHERN OHIO

*Yellow Transparent, *Duchess, Early Harvest, Liveland Raspberry, *Maiden Blush, *Wealthy, Richard's Graft, *Grimes Golden, *Jonathan, Corp's Choice, *Rome Beauty, Ensee, *Rawles Janet, *York Imperial, *Gano, *Stayman's Winesap.

The Baldwin in northern Ohio and the Rome Beauty in the southern part of the state are probably the most popular and profitable varieties for winter market. Grimes and Jonathan should be planted freely both north and south, especially for home use and for near market.

Pruning

There can be no iron-clad rules laid down relative to the pruning of a tree. No two trees are exactly alike and each one must be treated individually.

The object should be to preserve a symmetrical, well-balanced top, open in the center, without crowding of the branches in any part.

All branches which grow toward the center of the tree, and those which cross or interfere with each other, should be removed. A fine-toothed pruning-saw is best for this purpose and the cuts should be made smoothly and close to the body or main branch of the tree from which the superfluous branch is pruned. There is usually a

little ring or enlargement at the base of each branch; the saw-cut should be made midway and downward through this



The perfect healing of a wound made by pruning away a branch



Where branches should be cut in pruning apple trees. Such wounds readily heal

enlargement. If one branch of a tree makes an over-vigorous growth and outstrips the others, it may be cut back so as to secure uniform outlines of the head or top. The little twigs and spurs forming along the larger branches should not be cut off as the trees attain considerable size. Those very twigs and spurs are the parts of

the tree which will first bear fruit.

APPLE CULTURE IN OHIO



In need of attention. Wealthy apple tree grown unsymmetrical and in danger of breaking if heavily laden with fruit. Needs thinning also

Renewal of old Orchards Nearly every Ohio homestead has a greater or lesser number of old apple trees—usually of desirable varieties. As a rule they have attained

such extreme size and height that it is with great difficulty that the all-important work of spraying can be accomplished. If these trees were originally headed quite low and yet retain their lower branches in fairly vigorous condition, the topmost branches may be cut back severely, lowering the height of the trees materially and rendering the work of spraying, gathering fruit, etc., much more readily done. The type of trees which cannot be successfully headed down are those which have long, naked branches extending to a considerable height before diverging into smaller branches. In heading back an old tree it is well to make the cuts just above diverging branches, if possible, as the wounds thus made will heal much more easily than if made midway between diverging branches. All wounds should be well painted with a thick, lead and oil paint.



Wealthy apple tree after heading in and thinning, its symmetry restored

Heading back large trees will result in a vigorous growth of young shoots springing up from the upper branches, and in the entire tree taking on new life. The stronger shoots in the tops of the trees should not only be thinned out each season where too thick, but those remaining after thinning should be cut back with the pruning shears from one-third to one-half their length. In a few seasons this new wood, thus restricted, will begin to form fruit buds and bear fruit. In the meantime, with thorough fertilizing, cultivation or mulching and spraying of the trees, their lower parts should be producing plenty of fine fruit. (See Bul. 180).

No matter how careful may be the cultural methods employed, our orchards will fail to respond satisfactorily if the various insects and fungous diseases are not combated by spraying. Indeed, there is no orchard operation which will more largely reward thoroughness in work than spraying. We have met men who declare spraying does

not pay—for they “have tried it.” But invariably close inquiry has developed the truth that they either used improperly made mixtures or failed to do the work well or at the right time. The man most difficult to convince of the benefits of spraying is the man who in the past purchased a \$2.50 bucket or knapsack sprayer, used poorly prepared mixtures—perhaps mixtures entirely unsuited to the purpose—“sprinkled” a little here and a little there among his trees and, concluding it was too much work, gave it up as a failure. Such a man would be surprised to see the effective work of a really good spraying outfit and the remarkable results attending its intelligent use.



“Veahthy apple tree bearing a heavy crop of fine fruit the same year of heading in.

For a number of years Bordeaux mixture has been the most efficient and popular remedy for all fungous diseases of the apple and other fruits and plants. The most prevalent and serious fungous diseases of the apple are the apple scab, the sooty fungus and various forms of rot. A veritable scourge in Ohio is the scab

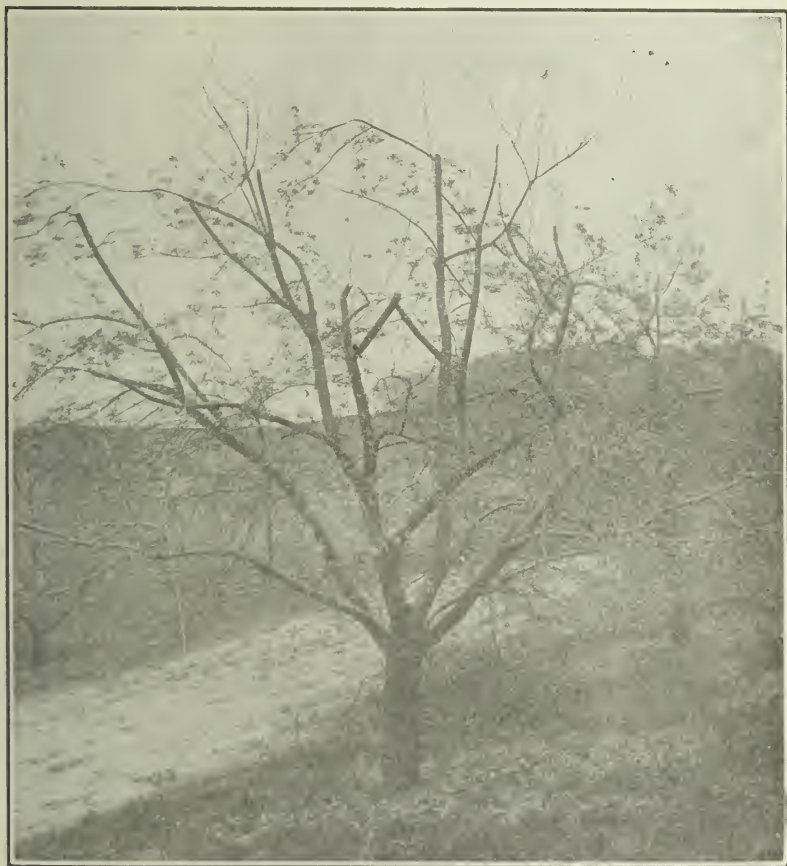
fungus—especially in seasons of excessive rainfall; yet this and all other fungous troubles can be almost entirely prevented by timely and thorough treatment with Bordeaux mixture.



A Lankford apple tree broken by heavy crop production and in need of heading in

The more destructive insects which infest the apple orchard. are the San Jose scale, codling moth, canker worm and curculio. The San Jose scale cannot be poisoned but must be controlled with a strong lime and sulphur spray, thoroughly applied to the trees

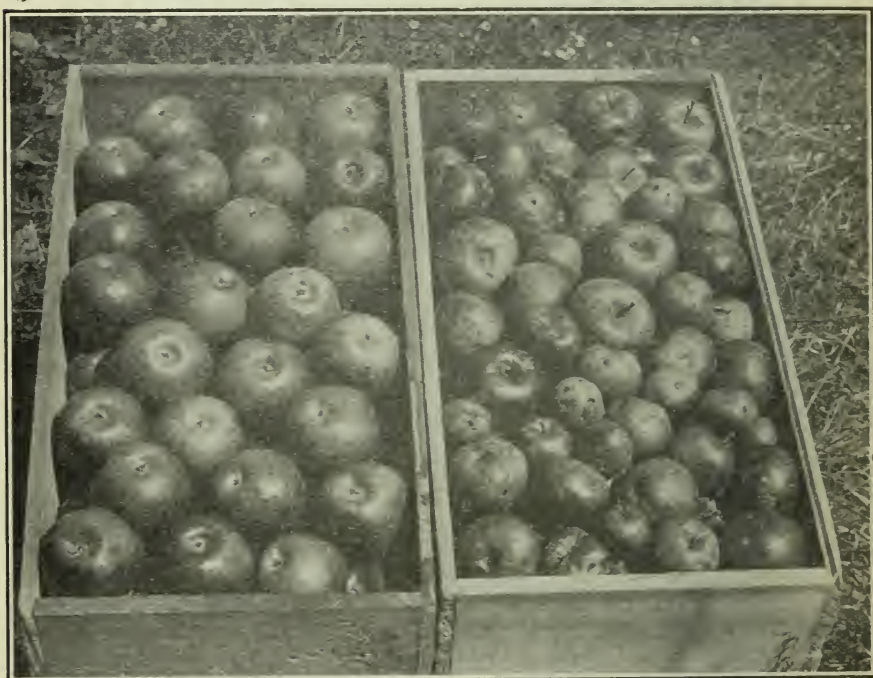
while they are dormant, preferably just as the buds are swelling in spring. The other insects named take their food by eating the tissue of the foliage or the flesh of the growing fruits, and may be readily poisoned. Various poisons have been used in the past with different degrees of success; but arsenate of lead is the approved poison at the present time, as it is not only very effective, but remarkably lasting, adhering to the foliage and fruit throughout a long, growing season without losing its efficiency. The Bordeaux mixture and the arsenate of lead are successfully combined so that both fungous and insect foes may be combated at the same time.



Lankford apple tree after heading in.

The form or type of spraying outfit to be used should be determined by the amount and character of work to be accomplished. For an ordinary farm orchard of 25, 50 or 75 large trees, or a young orchard of perhaps several hundred trees, a well-made,

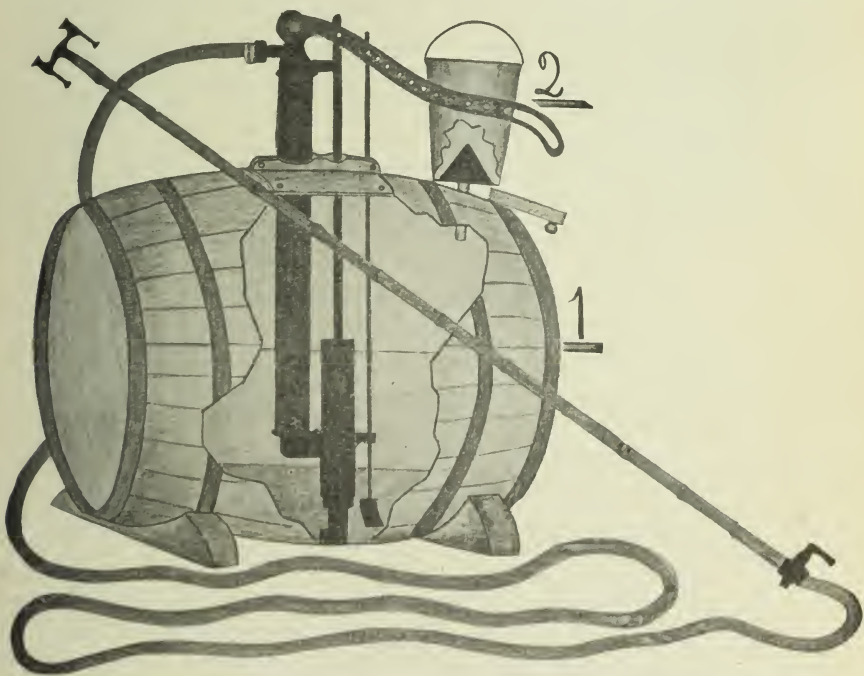
all-brass barrel pump of ample capacity will give good satisfaction. It is advisable to buy a pump of such size that there may be a surplus of capacity rather than one that is insufficient in this respect. The work can be accomplished with less exertion on the part of the operator, and with less wear of the outfit, if the pump be of generous capacity. In choosing a pump make sure, also, that it is fitted with an effective mechanical agitator—an attachment that will keep the spray mixture in the barrel or tank well stirred while the pump is in service. There should be a long line of spray hose—not less than 25 feet if the work would be most easily and readily done. There should be an extension tube 8, 10, or 12 feet in length, according to size of the trees to be sprayed. The best form of extension tube is made of bamboo with a brass or aluminum tube running inside and connecting the hose at the base of the rod with the spray nozzle at the point. There should be a stop-cock at the base of the rod where it connects with the hose.



Sprayed and unsprayed Rome Beauties just as they came from the trees

A well-made barrel of 50 gallons capacity is recommended for the home orchard. A vinegar or kerosene barrel will serve the purpose well. A number of buckets will be needed—wooden buckets are by all means to be preferred—and these may be purchased very cheaply of any candy dealer.

Another indispensable part of a spraying outfit is a suitable strainer, through which to strain the spray mixtures into the barrel or tank, thereby preventing trouble from clogging of the nozzles of the outfit. A very simple, efficient and inexpensive strainer may be made of a common 10-quart galvanized iron bucket which may be purchased of almost any hardware dealer. Have the tinner cut a round hole 1 $\frac{1}{4}$ inches in diameter in the center of the bottom of the bucket, over which, on the outside of the bottom, have soldered a tube of the same diameter, six inches in length. On the inside of the bucket, covering the opening in the bottom, have soldered a cone of very finely perforated sheet brass, such as is used over the ends of pump rods in driven wells. The cone should be about 5 or 6 inches in diameter at the base and the same in height. Such a strainer will not clog when the materials are strained through it—the sediment rushing off to the base of the cone while the central part remains open and unobstructed.



Spraying outfit for small orchard. An outfit of this type should cost not exceeding \$20.00

The materials necessary for spraying for fungous diseases and leaf and fruit destroying parasites are copper sulphate, (blue vitriol) lime and arsenate of lead. Copper sulphate is purchased in crystal form by the barrel of 400 or more pounds, or in lesser

quantities as the buyer may choose. The most convenient form of lime is the "hydrated" or "ready-slaked" builders' lime which is put on the market in airtight paper bags, and may be procured from almost any of the larger builders' supply firms. Fresh burned stone lime is excellent, but requires the additional trouble of slaking. The arsenate of lead is in paste form and is sold in barrels, kegs or buckets according to the quantity desired.



Equipment and materials necessary for spraying small orchards

FORMULA FOR THE BORDEAUX MIXTURE

Copper sulphate [blue vitrol].....	4 lbs.
Lime [hydrated].....	6 lbs.
Water to make.....	50 gals.

Note: If fresh-burned stone lime be used 4 or 5 lbs. will be sufficient.

Where considerable spraying is to be done it is a great saving of time and work to make up a *stock solution* of copper sulphate. This requires a second barrel which should be provided with a good cover. Let us suppose that this "stock" barrel is of 50 gallons capacity: into it pour 40 gallons of water. Then weigh out, in a burlap bag, 40 lbs. of copper sulphate—or just as many pounds as there are gallons of water in the "stock" barrel. Now suspend the bag of copper sulphate in such a manner that its bottom will extend an inch or two (not more) down into the water. In this position the copper sulphate will readily dissolve over night, or less time. The mistake is often made by the beginner of hanging the bag of copper down deep in the water—submerging it. This mistake will result in the copper dissolving very slowly; a part of it may not dissolve at

all, as the water near the bottom soon becomes a "saturated solution" or, in other words, so heavily charged with copper that it loses its dissolving power. With the bag of copper sulphate suspended as advised, with its bottom merely touching the surface of the clear water which remains at the top, dissolution continues unrestricted until the contents are entirely reduced.

MAKING THE BORDEAUX MIXTURE

In preparing a 50 gallon barrel of Bordeaux, measure out from the "stock solution" 4 gallons, straining it into the spray barrel. Immediately dilute this quantity by adding enough water to make the barrel at least half full. Do this before adding the lime—it is important. If the mistake should be made of adding the lime to the strong solution of copper as it comes from the "stock" barrel, a curdled mass would most likely result—one that would not be so effective as a spray and one that might give trouble by clogging the spray nozzles. The spray barrel now being half full of the weakened copper solution it is ready for the lime. Weigh out 6 lbs. of hydrated lime and mix with water by stirring. Continue adding water and stirring and pouring into the several buckets until a quantity of 10 or 12 gallons of thin whitewash or milk of lime is obtained. Then slowly strain this thin lime solution into the spray barrel, briskly stirring the contents with the agitator of the pump whose plunger rod has been disconnected from the handle. This will result in the formation of a bright, sky-blue mixture free from curdling. The arsenate of lead should next be added. Weigh out 3 lbs. of lead, add a little water and stir briskly until it becomes a thin paste. Continue adding water and stirring until the solution is of such consistency as to readily go through the strainer into the spray barrel. Thoroughly agitate the mixture again just before beginning to spray after reaching the orchard.

THE TIME TO SPRAY APPLES

Give the *first spraying* just before the blossom buds open. The arsenate of lead may be omitted from this spraying.

The *second spraying* should be given as soon as the blossoms have fallen and while the little apples are yet remaining in upright position. Use the arsenate of lead in the Bordeaux for this spraying.

Give the *third spraying* ten days or two weeks after the second, using both arsenate of lead and Bordeaux again.

If a fourth spraying be given, which is almost always profitable, use the arsenate of lead alone about the 1st to 15th of July. This late spraying is to kill the second brood of the codling worm and to thereby prevent the "winter wormy fruit."

Spray the tree thoroughly—until every leaf, twig and branch is fully covered and beginning to drip. It may require 6, 8 or even 10 gallons of spray mixture to so fully spray a large tree, but count the time and material well spent.

The cost of spraying will range from 50 cents per tree, for 25- or 30-year-old trees, down to 15 cents per tree for 10- to 12-year-old trees for the season of three sprayings, this including the cost of the material and the labor. The fourth spraying would add a small amount to these estimates. The benefits to be derived from of this expenditure of material and labor may be realized by a reference to the tabulated results of the Experiment Station's demonstrative work in south-eastern Ohio during the season of 1909, as recorded on succeeding pages of this bulletin.

While the Bordeaux mixture has been the panacea for nearly all fungous troubles for a number of years and no doubt will continue to be largely used for some time to come, it is not, in some respects, a perfectly satisfactory fungicide. The Bordeaux mixture, especially in very rainy seasons, is likely to do some injury both to foliage and fruit, though by no means to such an extent as the diseases for which it is applied. Some of the leaves of apple trees turn yellow and drop prematurely and Bordeaux mixture aggravates this trouble; and it has a tendency to russet the fruit of some of the more susceptible varieties of apples. However, in case of the Rome Beauty, the predominating variety in southern Ohio, the Bordeaux is an almost perfect remedy for the scab and other fungi which so seriously affect it. This variety requires a strong fungicide and nobly responds to it, rarely showing a trace of injury by russetting of the fruit from the use of the standard strength of Bordeaux.

Our scientific men have not ceased their investigation and experiments in seeking a still more perfect fungicide, and their labors promise to be—possibly already are—rewarded. There is strong probability that the commercial preparation of lime and sulphur will gradually take the place of Bordeaux mixture, aside from its being the standard remedy against the San Jose scale.

A thorough and more extended test of lime-sulphur in comparison with Bordeaux will be at once inaugurated under various conditions and on many varieties of apples round and grown in Ohio.

Thinning

A new problem promptly presents itself along with the first results of thorough work in spraying—overloading of the trees with fruit. The trees set and persistently retain, oftentimes, twice, thrice or four times the number of apples that they can mature. Where these conditions occur there is no work that will pay better returns than carefully thinning the fruit. A surplus apple or a defective apple should be considered as a “weed apple”, as it will not only be worthless itself, but will prevent the fullest development of the perfect apples which it crowds. It is an excellent plan to relieve overloaded trees by removing the defective apples and thinning those remaining until they hang from 6 to 8 inches apart. The total quantity in bushels, at picking time, will not be appreciably lessened, because individual specimens of the smaller number of apples will attain much larger size.

In addition to the profitable results of thinning, so far as the size and quality of the fruit is concerned, the effect is very beneficial to the trees in various ways, assisting them materially in retaining health and vigor and promoting in a greater or lesser degree a regularity of crop production.

In Conclusion It has been endeavored, in this chapter, to briefly discuss the essentials of apple culture in a way that will be helpful to the many orchard owners who are awakening to the possibilities which lie within their reach. The writer has dealt only with the principles which enter into *production* of sound, perfect, profitable fruit. Cultural essentials by no means cover all the important factors of successful apple growing. After the crop has been produced a very great deal depends upon how it is handled. Picking, grading, packing, storing and marketing constitute a remarkably promising field for individual resource and ability from a business standpoint. But this is another story.

REPORT OF DEMONSTRATIVE WORK IN WASHINGTON COUNTY, 1909.
SPRAYING FOR CONTROL OF APPLE SCAB

A once profitable industry in southern Ohio; its downfall

Various localities in the eastern and southern portions of Ohio were, at one time, prominent as apple producing sections.

Especially were the counties bordering the Ohio river noted for the great quantity and fine quality of their Rome Beauties, Roxbury Russets (known locally as “Putnam”, “Marietta” or “Belpre” Russets) and a few other varieties, grown

along the valley and back among the hills, and shipped by thousands of barrels annually in barges which carried them to southern markets and, to some extent, to the more adjacent markets of Pittsburg, Wheeling and Cincinnati.

In those early days the fruit grew perfect and beautiful, and production seemed limited only by the extent of the acreage. For these great crops, handled by methods similar to those now employed in moving potatoes in large bulk, very low prices were obtained, as compared with prices ruling at the present time for stock of like quality. Nevertheless, the apple orchards of the southern part of Ohio brought to their owners satisfactory returns for the remarkably small outlay of labor, time and expense incurred in their maintenance. It was an epoch of prosperous and happy days; but the very ease with which fine apples were grown fostered indifferent methods of orchard management, and illy prepared the more thoughtless and careless owners for the problems which were slowly but surely developing for the future and which have, indeed, proved to effectually baffle by far the greater number of growers, and to bring a rapidly growing industry to an abrupt and humiliating termination. So long as the orchards remained fruitful under the easy-going manner in which they were maintained, apple trees were freely planted; but with the advent of trouble, which came as a natural sequence of neglect to combat threatening elements of stealthy approach, planting of orchards was almost entirely discontinued.

Within quite recent years utter discouragement has fallen upon this once thriving section, with the exception of here and there an individual orchardist who has closely and studiously followed the work of our scientific investigators, and promptly availed himself of such measures of relief as have from time to time developed.

An inquiry by In the winter of 1908-9 the Experiment
the Ohio Experiment Station sent out many letters to orchard
Station owners in the southern part of Ohio,
requesting that those who possessed apple
orchards and were yet interested in orchard improvement, would
respond by writing the Station stating their acreage in apples, the
condition of the trees and soils, what was being done to improve
those conditions, and any other information that might enable the
Experiment Station to get into closer touch with the once successful
but now inactive orchardists. But few replies to these letters were
received—these coming from widely scattered points. As an
instance which will especially serve to point this fact it may be
stated that from Washington county, south-eastern Ohio, there came

responses from but three orchard owners. This was a most surprising thing, inasmuch as it was known that Washington county was at one time the foremost apple producing county in Ohio, with over 7000 acres of apple orchards, or nearly double that of the average counties of the state. It was therefore arranged that a representative of the Horticultural Department of the Station should make a visit of inspection to Washington county, study conditions, gain the viewpoint of the discouraged orchardists and recommend such measures, both to the growers and to the Station, as might seem necessary to give relief.



Defoliation by apple scab fungus. Photo taken September 16, 1909

Apple scab fungus
scourge of southern
Ohio orchards

Accordingly the writer proceeded to Washington county, first going direct to the farms of the three gentlemen who had responded to our letters of inquiry, and subsequently mingling with many other orchard owners with whom we had not, previously, had any acquaintance or communication.

Various reasons were given, by these south-eastern Ohio orchard owners, for the comparatively recent failure of their trees to bear fruit as formerly. They stated that the trees continued to bloom profusely, as a rule, and appeared most promising early in the spring; but that the blossoms would wither, dry up and fall, or the little apples turn yellow, die and drop. It was explained, moreover, that the foliage of the trees would, later in the season, become spotted, yellowish and sickly and drop prematurely. That the few apples which did succeed in hanging on the trees were hard, gnarled, scabbed, blackened and almost worthless. The reasons given for these deplorable conditions were almost as various as the several growers visited. Some attributed the trouble to warm periods of weather in February or March, followed by extreme cold; others to cold winds in April and May; others to cold rains during the same months; others to late frosts; others to a gradually changing climate in general. A number of growers declared their belief that the varieties so long grown in that section had "run out"; that the Rome Beauty—the variety greatly predominating throughout south-eastern Ohio—had so deteriorated that it was no longer worthy of planting. Those who had orchards in the Ohio river valley or the lower levels of the smaller valleys opening into the valley of the Ohio, were confident that it was no longer of any use to attempt to grow apples, because the fruit was rendered black and worthless by "fog stain" even when it partially escaped the more serious, accompanying trouble which distorted, scabbed and dwarfed its development.

Listening, it is trusted, with ample patience and surely with much real sympathy to these complaints which, while varied somewhat, gave an unmistakable clue to the real trouble, the writer made a note of these facts: First and foremost that practically no spraying had been done, and that the few who had attempted it had either worked with inefficient outfits or with improperly made mixtures, or both; that southern Ohio had simply entered upon an era of a terrific scourge of fungous diseases of the apple, which the climate of that section especially favors; that the apple scab fungus was the principal cause of the withering and dropping of the blossoms and newly-set fruits and the spotting, yellowing, browning and premature dropping of the foliage; that the sooty-blotch or fungus was responsible for the "fog-stains" which besmirched the apples in the low levels, where the humidity of the atmosphere highly favors its development; that the codling moth and curculio came in for their share in destruction, and swept away such remaining portions of fruit as partially or wholly escaped the

fungous diseases; that the greatest error into which the orchard owners had fallen was their belief that the Rome Beauty and other erstwhile dependable varieties of apples had "run out." The fact should here be emphasized that there is, so far, no variety known that is so excellently adapted to southern Ohio (its home), and none that so easily, quickly and generously responds to spraying as the Rome Beauty. It is seriously subject to fungous disease of both foliage and fruit, but it is the embodiment of perfection when properly sprayed.

**The Experiment
Station to the
rescue**

Hastening a report of conditions back to the Horticultural Department of the Station, recommendation was made that a few simple but efficient spraying outfits, with chemicals, be rushed to Washington county, where a number of demonstrations in fungus and insect control might be made in at least the orchards of the three men who had responded to the Station's letters of inquiry. As the time for spraying was at hand by the time the outfits and materials arrived at their destination, Station employes followed and personally made and applied the mixtures, spraying representative blocks of each orchard, chosen for the demonstrations. The owners co-operated by furnishing the necessary teams and drivers, and closely observed the making of the mixtures and the thoroughness of the applications. Rows or single trees were left unsprayed as "checks" for comparison with the sprayed rows or trees. The greatest of care was taken in the choice of these check trees, that only such as were fully equal to the best of the trees to be sprayed, might be selected. In every case the check trees had blossomed as profusely and were apparently as vigorous as the trees sprayed alongside. The first spraying was given as soon as the petals of the blossoms had fallen. We should have preferred to make this first spraying just before the blossom buds opened, but it was too late by the time the outfits were at hand.

Very soon a distinct difference was apparent between the sprayed and unsprayed trees. The little apples on the sprayed trees promptly sprang into evidence plump, bright and persistent. From the unsprayed trees the little fruits dropped by thousands, withered and yellow from the early attack of the apple scab fungus; the ones remaining soon began to develop rough, darkened spots that enlarged until the fruits were gnarled and deformed. A second spraying was given two weeks after the first, and a third and last about the first of July.

As the season advanced the difference between the sprayed and unsprayed tree became more and more clearly marked. In June the sooty fungus came with alarming severity, sweeping through the valley orchards and blackening the unsprayed and already otherwise terribly deformed fruit; but the three thorough sprayings kept the heavy loads of apples on the treated plots smooth, bright, plump and perfect. The results of this thorough spraying were simply marvellous when it is considered that it was the first season's work in the very midst of one of the most seriously diseased and insect infested areas in Ohio. In addition to keeping the fruit remarkably free from the dreaded scab fungus, there was practically no evidence of sooty fungus, and the codling worms and curculio which were in generous evidence among the unsprayed apples were almost entirely barred from operations in the sprayed sections.

DETAILS AS TO ORCHARDS AND SPRAYING IN WASHINGTON COUNTY

The orchards;	The orchards included in the demonstra-
the owners;	tive work in spraying, in 1909, were those
the location	of J. C. O'Neal, of Belpre, J. H. Riggs, of
	Little Hocking, and Chas. W. Oakes, of
	Armenia—all within sight of the Ohio river, and either within its
	valley or upon the adjacent hilltops.

The O'Neal orchard is situated on a very high hill one mile north of Belpre and overlooking the Ohio River and valley and the town and city of Belpre, Ohio, and Parkersburg, W. Va. The land on which the orchard is located is thin, is in grass and had been pastured for a number of years. The location exposed the trees to extremes of cold and heat, and they had especially suffered from protracted droughts, which baked and parched and cracked open the thin, hard soil of the hilltop. The trees were 30 years old. The orchard was at one time generously fruitful of beautiful Rome Beauties and a few other varieties, the apples attaining very high color because of the elevation, exposure to sunshine and the peculiar red clay soil which abounds at certain elevations throughout that section; but in recent years it had not produced enough sound fruit for the home use of the owner. This orchard, in 1909, did not blossom uniformly, presumably from the effects of the very severe drought of the preceding season—only the more favorably situated trees being enabled to form fruit buds. Previous onslaughts of apple scab had also done much to devitalize the trees by destroying the foliage early in the season. A number of the trees bloomed profusely, quite a proportion scatteringly and a few



A Rome Beauty tree after years of crop failures through infestation of fungi and insects, bearing a crop of 12 bushels of sound, perfect, long-keeping apples.

Orchard of J. C. O'Neal, Belpre

not at all. Mr. O'Neal expressed his opinion that never again would he be privileged to see his trees produce sound, perfect fruit. Much to his surprise and delight, however, the trees which had blossomed freely and were thoroughly sprayed produced remarkably heavy crops of as fine or finer fruit than he remembered ever to have seen in the early years of the orchard. The trees which bloomed sparsely and were sprayed bore a partial crop of equally fine fruit, while the unsprayed trees, no matter how profusely they had blossomed, bore but a very insignificant quantity of miserably deformed, scabby, worthless specimens, which he considered not worth picking. From the sprayed trees Mr. O'Neal had the pleasure of gathering and storing over 100 bushels of choice apples which he sold to his neighbors in the village at \$1.00 per bushel without grading. Mr. O'Neal sees renewed possibilities and opportunities in this excellent orchard and is preparing to spray and otherwise care for it in the future. He is using his entire crop of corn stover, grown upon the hill in a field adjoining, for mulching

his trees which have heretofore been suffering from lack of food and moisture, and declares that he is confident that this fodder, used as a mulch, will bring him far greater results than selling it at the usual prevailing prices.

An excellent water supply was available in Mr. O'Neal's hill-top orchard. Having become wholly discouraged with his orchard he utilized the area for pasture. As no water was in the orchard he built a large cistern on the summit of the hill. Over the opening of this cistern extends one end of a shed probably 12x18 feet in size. This shed is covered with galvanized steel roofing, and an eaves-trough is attached by which water from rains and melting snows is conducted into the cistern. So convenient was this water supply, and so valuable a suggestion for other owners of hilltop orchards, that attention is called to this feature as one worthy of following elsewhere. The shed, aside from supplying the cistern with water, provides shelter for tools, spraying equipment, barrels, crates, baskets, and workmen in time of rain.



A high hill top in Washington county. The water for use in spraying this orchard is gathered into a large cistern, the curb of which is just inside the orchard tool-house.
Orchard of J. C. O'Neal, Belpre

The Riggs orchard is situated 8 miles farther down the Ohio river and one mile from the station of Little Hocking. This orchard is also located on a high hill. The trees were 12 years old and of Rome Beauty and Ben Davis varieties. While the trees of this orchard had been blooming profusely since they were seven or

eight years old, and had borne some fruit, the fruit had been defective from scab, sooty fungus, codling worms and curculios. The orchard was used for a pasture, but had received occasional top-dressings of manure hauled from a cattle shed nearby. About one acre of this orchard was sprayed, leaving in each row a "check" tree carefully chosen because of its average size, good health and vigor and profusion of bloom. The object lesson afforded by this orchard, showing the benefits of thorough spraying, was simply marvellous, as may be observed by reference to the tables showing yields and quality of products from sprayed and unsprayed trees.



Results of thorough spraying. A 12-year-old tree from which over 300 apples were thinned

The Oakes orchard is situated 10 miles below Belpre and on second bottom, Ohio river valley land. The trees, 450 in number, were 34 years old. This orchard had been widely noted for its abundant prolificacy of extra large Rome Beauties, which almost wholly compose the plantation, but had not borne perfect fruit in late years on account of the prevalence of apple scab and serious, annual infestation of sooty fungus, invited by the humidity of the valley conditions. This orchard was also being continually pastured. The owner was very much discouraged because of repeated failures of the orchard to bear and was seriously contemplating the cutting it down. In fact the only reason that

the trees were yet standing in the spring of 1909 was that Mr. Oakes failed to find anyone who would accept his offer of the timber for the work of cutting down the trees. A representative acre of this orchard was chosen by the Experiment Station, having obtained the consent of the owner to do some demonstrative work. Mr. Oakes himself assisted in locating this demonstration plot, and especially in determining the check trees to be left, so that he would know that the trees left unsprayed for comparison were fully equal in every respect to those to be sprayed. The trees were in full bloom when this selection was made. The result of this demonstration was that from the one acre sprayed Mr. Oakes sold over \$500 worth of fine Rome Beauties, leaving a net profit for the acre of \$474, after all expenses had been deducted. This object lesson was seen and studied by hundreds of orchard owners of southern Ohio during the season of 1909. The autumn meeting of the Ohio State Horticultural Society was held in the orchard, and numerous exhibits of sprayed and unsprayed apples therefrom made at Marietta, Barlow and elsewhere, including the State Fair at Columbus and the January, 1910, Apple Show in connection with the Annual Meeting of the State Horticultural Society. The results, personally, with Mr. Oakes, are that a new, power spraying outfit is already on the ground, and plans for the most excellent care of the old orchard are being formulated as well as plans for planting many acres of new orchard on adjacent land. Mr. Oakes stated that his *unsprayed* trees, in 1909, bore such poor, worthless fruit that he could not easily encourage his pickers to get up into the trees after it.



Sprayed
Sound and perfect 560

Unsprayed
Sound 0

Products of two Rome Beauty trees twelve years old. Fifteen cents worth of material and labor made the difference



An enthusiastic autumn meeting of the Ohio State Horticultural Society, in orchard of Mr. Chas. W. Oakes, Armenia

A tabulated statement of results of spraying in these various orchards follows. In making comparisons between sprayed trees, those of the same age and as nearly same size and degree of vigor as it was possible to determine, were chosen. Happily it was also possible to select these average trees so that they stood side by side in the O'Neal and Riggs orchards, and but a very short distance apart in the Oakes orchard. No fairer comparisons could reasonably be desired.

**Brief summary of
results of spraying in
Washington County
in 1909**

The spraying was done principally with Standard Bordeaux mixture as the fungicide and arsenate of lead as the insecticide.

However, in a few instances, half strength Bordeaux with arsenate of lead, half strength Bordeaux with sulphate of iron and arsenate of lead, and full strength Bordeaux with arsenate of soda were used. The first three tables present the results of one representative comparison between sprayed and unsprayed trees in each orchard—this comparison representing average conditions as nearly as could possibly be determined—where standard Bordeaux (4-6-50) and arsenate of lead (3 lbs.) were used.

In every case cost of crop includes materials for spraying, the work of spraying, the barrels, the picking and packing.

ORCHARD OF J. C. O'NEAL, BELPRE. TREES 25 OR 30 YEARS OLD

Variety Rome Beauty	Sprayed Tree No. 1	Unsprayed Tree No. 2
Sound, perfect apples.....	1445	4
Very slightly scabbed.....	591	53
Total marketable.....	2036	57
Cost of spraying three times.....	\$0.50	....
Total product in barrels.....	5 1-3	2-3 bbl.
Total value of crop.....	\$16.00	\$0.40
Total cost of crop.....	2.70	0.65
Net profit.....	\$13.30	-\$0.25

ORCHARD OF J. H. RIGGS, LITTLE HOCKING. TREES 12 YEARS OLD

Variety Rome Beauty	Sprayed Tree No. 1	Unsprayed Tree No. 2
Sound, perfect apples.....	560	0
Very slightly scabbed.....	142	55
Total marketable.....	702	55
Cost of spraying three times.....	\$0.15	....
Total product in barrels.....	2 1-6	3-4 bbl.
Total value of crop.....	\$8.66	\$0.75
Total cost of crop.....	1.13	\$0.48
Net profit.....	\$7.53	\$0.27

ORCHARD OF CHAS. W. OAKES, ARMENIA. TREES 34 YEARS OLD

Variety Rome Beauty	Sprayed Tree No. 1	Unsprayed Tree No. 2
Sound, perfect apples.....	1530	2 (mk'd sooty fg)
Very slightly scabbed.....	400	337
Covered with sooty fungus.....	37	966 (100 %)
Total marketable.....	1893 (1st class)	337 (2nd class)
Cost of spraying three times.....	\$0.50	....
Total product in barrels.....	4 3-4	1 1-4 bbl.
Total value of crop.....	\$14.25	\$2.19
Total cost of crop.....	2.60	.70
Net profits	\$11.65	\$1.49

An additional table showing results of spraying with different quantities and combination of materials is given below. Three counts were made from as many representative trees 34 years old.

There was very little evidence of presence of codling worms in this orchard.

ORCHARD OF CHAS. W. OAKES; VARIETY ROME BEAUTY

Character of fruit	Sprayed	Sprayed	Sprayed	Unsprayed
	Standard Bordeaux and arsenate of lead	Standard Bordeaux and arsenite of soda	One-half strength Bordeaux and iron sticker	Check tree
	%	%	%	%
Sound, perfect fruit.....	81.8+	92.3+	80.5+	00.2+
Very slightly scabbed.....	14.2	5.6	12.6	35.8
Deformed by scab.....	3.2	2.0	1.2	60.7
Marked with sooty fungus.....	0.6	0.0	5.3	100.0
Injured by codling worm.....	0.0	0.0	0.2	3.2

Following is a summary of results of spraying for control of apple scab in Washington county, 1909. The figures given present the average percentages of the different grades of apples, based on many counts from different sprayed and unsprayed trees in three different orchards:

	Sprayed	Unsprayed
	%	%
Sound, perfect apples.....	70	00.8
Very slightly scabbed.....	17	35.0
Deformed by scab (seconds and cull).....	13	74.2

For formulae for making all kinds of spray mixtures for various fungous diseases and insect enemies of fruit and vegetable crops write the Experiment Station at Wooster, Ohio, requesting Spray Calendar (Bulletin 199) which will be mailed free.

BULLETIN

OF THE

Ohio Agricultural Experiment Station

NUMBER 218

JUNE, 1910

THE STATUS OF THE POTATO GROWING INDUSTRY IN OHIO

By F. H. BALLOU

Potato culture, in Ohio, is rapidly developing into a vast industry. The crop of 1907—the last year for which statistics are available—reached the enormous aggregate of 10,825,659 bushels. Among the staple products of Ohio soil, potatoes, therefore, rank fourth in the number of bushels produced—corn being first, oats second and wheat third.

Roughly dividing the state into four parts by drawing an imaginary line from Sandusky on the north to Ironton on the south; and from Bellaire, in Belmont county, on the east to Greenville, Darke county on the west, we find that, in the northeastern quarter were grown in 1907, approximately 5,800,000 bushels, or more than one-half of the total production of the entire state.

The ten heaviest potato producing counties of Ohio are Portage, Wayne, Medina, Cuyahoga, Hamilton, Stark, Lucas, Summit, Erie and Mahoning, named in the order of their yields for 1907, beginning with the highest. The same counties have maintained their precedence as the banner producers for the past ten years, although the order of individual yields may have been transposed occasionally—especially those noted for close competition. Seven of the ten heaviest producing counties, in 1907, were embraced wholly within the northeastern quarter; also the greater part of another—Erie. Lucas county, the seventh in point of production, and a small part of Erie, are in the northwestern quarter. Hamilton county, the fifth in point of production, in 1907, contributes this distinction to the southwestern quarter.

While these figures and data are interesting, they should by no means be construed to suggest that outside of the sections and counties named this industry is not followed with success and profit,

nor that potatoes of equally as fine quality cannot be grown. The valleys of the Great Miami, Little Miami, Scioto, Licking, Hocking, Muskingum and other rivers and their hundreds of tributaries, as well as many fertile, upland soils in various other parts of the state, yield fully as high an average per acre in bushels, and equally as good potatoes as relates to table quality.

The ten lightest potato producing counties of the state, during the period of the last ten years, are Fayette, Union, Highland, Madison, Harrison, Preble, Warren, Adams, Jackson and Gallia. Of these counties, during the period of the last ten years, Fayette stands notable as the least devoted to potato culture, therefore producing the least number of bushels, of any county in Ohio. Its average for the ten years is about 7,200 bushels per year. Only 580 bushels were grown in Fayette county in 1907. This county will illustrate the fact that the status of the potato growing industry in different counties is determined not by the degree of fertility or productivity of the soils of these counties, but by the branch or branches of agriculture or horticulture which are specialized by the land owners thereof.

In addition to the regular lines of potato work at the Experiment Station there has been considerable material of a miscellaneous nature gradually accumulating through special experiments and careful observations both at the Station grounds and throughout the state, which should be of much practical value to the potato grower, especially the beginner. The more important features of this accumulated fund of practical information are now assembled in this bulletin, inasmuch as it was considered that such a publication would clearly and fully answer many oft-recurring questions from correspondents, which cannot be fully and satisfactorily answered within the limited scope of personal letters to each one.

ROTATIONS FOR POTATOES

An excellent rotation for the potato farmer is a three-year cycle of potatoes, wheat and clover. Barnyard manure, unless it be well rotted, in this rotation is preferably used as a winter top-dressing on the wheat or clover. It is not advisable to plow under fresh stable manure in preparation for potatoes, as such manure favors conditions under which the tubers are likely to be more or less attacked by the scab fungus, thereby blemishing a portion of the crop. The aim should be to induce a strong growth of clover, and to this end lime may often be used to advantage on the wheat preceding the clover crop.

Another good rotation for the potato grower who is also engaged in strawberry growing, is clover, potatoes and strawberries. In detail, the strawberry bed is plowed under at the close of the first or second season's fruiting, the soil finely and firmly worked down and medium red clover immediately sown at the rate of 15 or 20 pounds per acre. This plan of mid-July clover seeding has rarely met with failure under the writer's observation or practice. If the season be at all favorable the clover will make a good growth the same season of sowing. A crop of hay may be taken the following season, the second growth being allowed to remain on the ground to be turned under the following spring. Potatoes follow the clover, and after these are harvested rye is sown as a winter cover crop to be turned under the succeeding spring in preparation for strawberries. This plan provides for a four-year rotation if a single crop of strawberries be gathered, or a five-year rotation if two crops be harvested. Other garden crops may be substituted for the strawberries if the grower desire. A late crop of potatoes, using sprouted seed, may also be grown after strawberries. This plan is usually very satisfactory if properly carried out, often giving a yield of potatoes equal to or greater than the early planted crop. The strawberry bed should first be thoroughly disked and then plowed and carefully harrowed, then rolled and harrowed again. Wheat and then clover follow the potatoes.

PREPARATION OF THE SOIL AND METHOD OF APPLICATION OF FERTILIZERS

The question is often submitted: "Is it a commendable plan to plow ground, intended for potatoes, in the autumn or during open periods in the winter?" Fall or winter plowing might be advisable under certain conditions. These conditions would depend principally upon the character of the soil and the amount of work to be done with a given force of help. If the soil be tenacious clay or heavy clay loam, plowing too far in advance of the planting season would certainly result in the soil becoming so compacted by late winter and early spring rains that preparation of a deep, mellow seed-bed would be a difficult proposition. Lighter clay loams abounding in humus, or soils of a sandy nature, might safely be plowed in autumn or winter, providing they are so situated that there is no great danger of loss of soil and fertility by washing, as would be the case on steep hill-slopes. In any case where fall plowing is practiced it is well to work the ground as deeply as possible in the spring with a disk harrow or two-horse cultivator. Those who farm level or comparatively level land do not realize the importance of great care in this respect in the hilly sections.

In a general way it may be stated that the better plan is to plow potato ground as early in the spring as the ground becomes in good condition to work. In sections of the state where early planting is practiced it is the custom to plow, prepare and plant at once. In other sections, as in certain parts of northern Ohio, where June planting is the rule, the ground may well be plowed as soon in the spring as it will work well and harrowed every week or ten days until the chosen time of planting arrives. This will result in the germination of millions of weed seeds and the prompt finish of the tiny plants. In any case the ground should be worked down until the soil is fine and the surface level and smooth.

After experimenting with different methods of application, the Experiment Station now favors and practices drilling in commercial fertilizer by the use of a common grain drill with fertilizer attachment. This is done after the ground has been harrowed once or twice and just previous to planting, where early planting is the rule. In case of late planting on early prepared ground a greater number of harrowings would, of course, precede the fertilizer application, which would be delayed until planting time. By this means of application the fertilizer is distributed evenly over (or rather in) the entire area where the feeding roots of the potatoes will readily find it as they freely extend through the upper soil. By this uniform distribution of the fertilizer the potato plants not only more fully profit by the application, but the surplus food, left in the soil after the maturity of the potatoes, will be evenly distributed for the wheat, rye or other crop which may follow. The modern horse potato planters are almost invariably provided with fertilizer attachments, planned only for distributing the fertilizer in the bottom of the furrow in a comparatively narrow line. While the crop, of course, benefits from this application, it does not by any means do so to the extent that would be possible were the plant food spread throughout the soil. Only a comparatively small percentage of the potato roots are found within the restricted limits of the three or four inch wide strips extending beneath the rows of plants. True the feeding roots of plants, according to one of the laws of nature, to some extent are attracted toward, concentrate and multiply about these rich sources of available plant food; but such concentration clearly means a greater or lesser degree of congestion or crowding and a corresponding and unusual drain upon the soil moisture of these restricted areas. This, especially in seasons of severe drought, is a condition of the feeding root systems of our plants not especially desirable and preferably not invited.

It is, of course, impracticable in planting by hand, small or garden areas for home use, to use a grain drill for applying the fertilizer. In these small patches it is a most excellent plan to open the

furrows with a large, broad-bladed, single shovel plow, leaving furrows approximately six inches deep and twelve inches broad at the top. The fertilizer is then applied by hand, scattering it not only in the bottom of the large furrow, but covering the sides or slopes as well. When the potatoes are planted in this furrow, covered, and the ground levelled down with a fine tooth harrow or cultivator, there will be spaces fully a foot wide along and beneath the rows, in which the fertilizer will be well distributed and mixed with the soil.

NORTHERN VERSUS HOME GROWN SEED POTATOES.

STORAGE

The widely prevailing belief that there is some special quality of superiority in northern grown potato seed stock, not possessed by our home grown seed, is responsible for many thousands of dollars being annually expended by Ohio potato growers for "northern grown stock." The Experiment Station is frequently called upon (especially by beginners in potato culture) to state whether there is just cause for entertaining such a belief and adhering to such practice.

It must be admitted that there is more or less abuse of the phrase "northern grown;" it is wonderfully elastic as commonly employed in the trade, and may signify much, considerable, little, or nothing at all. Maine, Vermont, Michigan or Wisconsin grown potatoes are truly "northern grown" stock as received and used by Ohio planters. Ohio grown stock is truly "northern grown" when used by planters in the southern states. Seed tubers produced in the Lake Erie district might, with some justification, be sold as "northern grown" to southern Ohio growers. But frankness prompts the suggestion that an indiscriminate selling, by dealers and seedsmen, of Ohio grown stock to Ohio planters, as "northern grown," approaches a travesty on the seedsmen's trade; it borders closely on deception and the getting of money under false pretence; it is, to say the least, making use of a "magic phrase" that has come to mean too much to the buying public and too little in reality. Happily, when the Ohio purchaser seeks northern grown potatoes and is supplied with Ohio grown stock that is plump, sound, bright and dormant; and if the conscience of the dealer become not a source of annoyance at these bits of deception, no one is materially injured—least of all the buyer; for, if the seed be as I described—well preserved and dormant—he will have secured as good stock for planting as the continent produces. But let us insist that this commodity be placed on the market for what it is; and let us judge its value as seed stock by its apparent purity as to variety and by its *condition* rather than by its source.

Excellence or inferiority of potato seed stock, therefore, depends vastly more upon its condition at the time of planting than upon the latitude or locality in which it was grown. The reason that northern grown stock has come to be noted for its superiority for a more southern latitude is because the seed is wintered in a lower degree of temperature in the more northern sections; it is kept sound and hard, crisp, fresh and dormant, and comes down to us at or just previous to planting time in this most desirable condition. It has lost none of its vitality through sprouting in storage. But, if seed tubers of our own growing be given similar storage conditions and is plump and dormant when spring comes, these are equal to the best stock in the market, no matter how far north it may have been produced. However, too often, our seed stock is wintered in too warm a storage, where it exhausts its vitality and becomes withered and shrunken through excessive sprouting. Especially is this true of stock wintered in cellars under dwellings.

The problem of storage, therefore, becomes the chief consideration and the determining factor of success as against failure for the professional potato seed grower, the dealer and the home or market grower who desires to produce his own seed stock. It is an especially important matter with the grower who is interested in the improvement of his favorite variety or varieties by careful selection from year to year. He must preserve his stock from season to season and preserve it in good condition if he maintain a continuity of the fascinating work and marked progress he is achieving in his chosen line of potato breeding. Those who make a practice of annually buying seed from another latitude or section as a rule do not realize or recognize the possibilities of, nor attach great importance to seed selection; and even if they do, it is not possible for them to take part in the maintenance of the high standard of a variety or its improvement by the potent means of selection of superior strains of that variety.

Not only extended observation, but carefully conducted tests at the Ohio Station, have shown that far northern grown potato seed stock is not superior to Ohio grown seed, if our home grown seed is well preserved. Bovee, Happy Medium, Gold Coin and Carman No. 3, seed from Maine, Michigan and Wisconsin was, in 1905, planted alongside seed taken from the cool, barn-basement storage on the Station grounds. The growing and yielding qualities of the home-grown stock was in every point fully equal to the northern grown seed. No more uniform plots could have been grown had the different plots of the same varieties been planted from the same seed-lots. But it must be admitted that our Station grown seed was in equally

as good condition at the time of planting as that from the more northern and colder latitudes. Had the seed of our own growing been robbed of its vitality by becoming excessively sprouted in a too warm storage, and withered and shrunken as too often home grown seed stock becomes, the results would doubtless have been in favor of the northern grown seed stock, as has often been proved in comparative tests.

A cellar or basement under the barn or some similar farm building can usually be converted into a suitable storage for seed potatoes. Storage cellars under outbuildings are much cooler than those under dwellings. The temperature of such a potato storage may quite readily be held at from 34 to 40 degrees, by reasonably careful attention. When a dangerously low degree of cold is threatening, a lantern, or small, oil stove may be kept burning in the storage room. To guard against possible danger from explosion, or overturning of the lantern or stove, and spreading of oil, the heating device should be set in a large metal pan, or a metal tub. If the temperature of the storage ascends to 40 degrees or above, through the influence of unusually high, daytime temperature, the outside doors or the ventilators should be thrown open during the colder temperature prevailing through the night time. This will usually lower the temperature of the storage and its contents to the desired degree. All outside openings should be provided with fine-meshed wire screens to exclude vermin when the outside doors are open.

Underground storage rooms or "caves," built in a hillside or on well-drained level situations, may be made to do excellent service for potato seed storage. The same means of controlling the temperature of these, as used in cellars of outbuildings, may be employed.

Potatoes may also be buried in out-door pits and kept in fine condition until planting time. A well drained location should be chosen for the pit—one from which the surface water will readily run away. The tubers are piled in conical, pyramidal or long, sharp-ridged heaps, and covered over with six or eight inches of clean straw. Over the straw is covered about six inches of soil. Straw is also spread on the ground in a circle a little distance back from the base of the pit; this is to prevent the ground thus covered from freezing, so that more soil may be readily available when desired. As soon as the first covering of the soil over the pit has become solidly frozen a second covering of straw is added, and over the straw another six inches of soil. The second stratum of soil is then allowed to freeze solid, after which a layer of bundles of corn stover or a heavy covering of straw is placed around or over the pit, to shade and maintain the low degree of temperature prevailing within. Potatoes wintered in this way come out clean, plump, fresh and unsprouted at planting time.

It is evident that as the preservation of seed potatoes in good condition for planting becomes more and more difficult as the southern limit of Ohio is reached, the advisability of procuring seed from more northern sections becomes a more important consideration unless some plan of cold storage is available. But in the northern two-thirds of our state, no great difficulty need be experienced in keeping home grown stock in good condition in carefully constructed outbuildings or barn storage rooms. Growers in the southern states resort to growing a second crop of potatoes from the seed of the first crop, in a single season. The second crop seed keeps in good condition for the next season's planting. This plan is not practicable for our latitude; but late planting of "sun-sprouted" seed tubers may be substituted, and an excellent quality of long-keeping seed stock produced for the following year's planting. Such seed stock is fully equal to second crop southern seed, and is better than much of the so-called northern grown seed found in the market.

"SUN-SPROUTING" SEED POTATOES AS A MEANS OF PRESERVATION AND PREPARATION FOR PLANTING

While it is impossible to preserve seed potatoes in good condition in a storage which combines a too high degree of temperature with darkness, semi-darkness or even slightly subdued light, it is



Fig. 1. Tuber exposed to direct sunlight for four weeks.

quite possible to keep them for several weeks, in late spring or early summer, when they are spread thinly on the floor of a bright sunny room. After danger of freezing weather is past they are even better placed out of doors in the direct sunshine. A series of shelves arranged one above another on the southern exposure of the dwelling or a farm building provides an excellent place for sun sprouting. The tubers are spread in single layers on the shelves and allowed to

remain until wanted for planting. Exposed to the full force of the sun's rays the tubers, instead of sending out long, white, tender, succulent sprouts as in poorly lighted storage, become hardened in

flesh and green in color, and very short, stubby, firm, green sprouts are developed by the eyes. Withering of the tubers is but slight as compared with that under conditions found in a warm, dark storage, and they will remain in the sunlight many weeks in good condition for planting. Photographs are herewith presented showing one tuber that was exposed to the sunlight four weeks and another that was exposed ten weeks. Such tubers, when cut one sprout to a piece and planted, send up strong plants in a surprisingly short time.

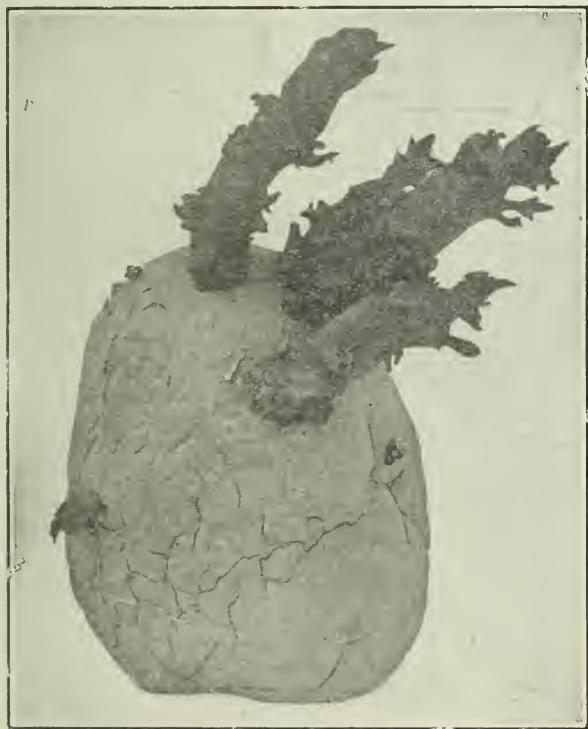


Fig. 2. Tuber exposed to direct sunlight for ten weeks.

It is hardly profitable to sun sprout large tubers for planting, as not all of the eyes will develop sprouts and considerable waste will result. However, the plan is excellent when smaller tubers are used and planted without cutting. So firm and tough become the hard short, sturdy sprouts developed in the sun, that planting may be done with certain horse-power machines without injury to the seed tubers if not too many are placed in the planter at a time. Planting of sun-sprouted seed is often delayed as late as the early part of July with excellent results in the production of a fine quality of seed stock for the following year.

Seed stock subjected to the prolonged "sun bath" does not require treatment for tuber infesting fungi, with formalin or corrosive sublimate. Bright, hot sunshine is, in itself, an effective fungicide. However, the usual recommended treatment with formalin seems not to produce any injury to the firm, green sprouts, as determined by a test in the season of 1908.

By the plan of sprouting the tubers of first early varieties in a sunny room early in the spring, the season of new potatoes for table use can be hastened nearly or quite two weeks, as was also demonstrated in 1908 in a comparison of sun-sprouted seed with ordinary cellar stored stock.

EXPERIMENTS WITH DIFFERENT QUANTITIES OF SEED POTATOES PER ACRE

The principle test work with potatoes in the season of 1906-1907, aside from the regular fertilizer and variety experiments, was the comparison of different quantities of seed per acre (determined by the different sized seed pieces used) planted in adjoining uniform plots of soil. The work was taken up in response to numerous inquiries from correspondents, and conducted with the utmost care and interest.

In this experiment were used, the first year, 10, 15, 25 and 40 bushels per acre, planting two standard varieties, Bovee and Carman No. 3, and duplicating the work in full so that dependable average results might be obtained. The second year's work was a duplication of that of the first year with the exception of one additional plot, representing a different rate of seeding with a different class of seed tubers not used the first season. This will be explained in its proper place.

The seed pieces were very carefully cut and accurately weighed in each and every rate of planting. In the 10 bushels per acre rows one-eye seed-pieces were used; in the 15 bushels per acre, two eyes; in the 25 bushels per acre, half tubers, and in the 40 bushels per acre whole tubers. The tubers throughout were smooth, of fine form and as nearly uniform in size as it was possible to have them in order to secure the desired weights from the different sized seed pieces. In order to overcome the now generally recognized tendency of plants to perpetuate, in the new generation, individual characteristics whether these be desirable or objectionable, not more than one seed piece from a divided tuber was permitted to be planted in a single test row. As an illustration: In the selection of seed tubers it is quite likely that we shall unwittingly choose an occasional tuber that was grown from a seed piece that produced in the hill a very small number of tubers. Perchance the

tuber we have chosen for planting was the only one of acceptable size produced by its parent plant; we do not and cannot know, unless we had selected the seed tubers from individual plants or hills the preceding season. Assuming that the unproductiveness of that particular hill was inherited from the parent seed stock, it is evident that we should make a grave mistake in dividing possibly the only good tuber from that hill and using it for planting a consecutive number of hills in a single test row. What is true of a tuber of inherent unproductiveness is also true of a tuber of inherent prolificacy.



40 bu. per acre

25 bu. per acre

15 bu. per acre

10 bu. per acre

Fig. 3. Heavy and light seeding.

Therefore, in order to render our test of more value and dependence, we first cut a tuber in halves. One half was used to plant one hill in the 25 bushels per acre section. One eye out of the remaining half went to form a hill in the 10 bushels per acre section. A two-eye piece from the same half-tuber found its way to a hill in the 15 bushels per acre section. If there were any eyes left from that particular half-tuber, they were discarded. Each hill of the 40 bushels per acre section of course required a whole or individual tuber, hence there was no division and no great danger of duplication of seed tubers from the same parent plant.

It was interesting to note the difference between the young plants of the different sections, as they pushed up through the soil in due time after planting. The difference in vigor of plants, for the first week or two, was decidedly in favor of the whole tubers. The plants from the one-eye pieces were at first much more slender than those from the two-eye pieces, half-tubers or whole tubers. These more delicate plants required greater care in the first cultivation, but the difference was not so apparent later on as the plants gained in size and vigor, and by the height of the growing season the individual stalks from the single-eye pieces were as large and strong as the stalks from the larger seed pieces.

As the rate of seeding per acre was increased, depending on the size of seed pieces used, in like proportion was the average number of plants or stalks per hill increased. Increasing the size of potato seed pieces, therefore, (with a corresponding addition to or multiplication of the number of eyes contained) is equivalent to increasing the number of grains per hill in seeding corn; and from extended observation in the past as well as from experiments conducted to obtain data for this bulletin, the results in either case may reasonably be expected to prove similar. By increasing the number of stalks per hill (up to a certain limit) the total yield may be somewhat enlarged, but this gain in yield is often at the expense of the size, development and quality of the product—whether this product be potato tubers or ears of corn. The following table shows the average number of potato stalks per hill from the different sized seed pieces used. One row of 45 hills was counted in each section:

BOVEE

Size of seed pieces	Rate of seeding	Total number of stalks in one row of 45 hills	Average number stalks per hill
One eye.....	10 bus. per acre	94	2+
Two eyes.....	15 "	144	3+
Half-tubers.....	25 "	282	6+
Whole tubers.....	40 "	495	11
Small tubers (2 oz.).....	22.6 "	356	7+

CARMAN No. 3

One eye.....	10 bus. per acre	92	2+
Two eyes.....	15 "	142	3+
Half tubers.....	25 "	181	4+
Whole tubers.....	40 "	232	5+
Small tubers (2 oz.).....	22.6 "	183	4+

It will be noted that in the above table that the large seed pieces of Bovee produced a correspondingly increased number of stalks to the hill, while the Carman No. 3 does not exhibit this tendency in

nearly so marked a degree. Indeed the Carman, as a representative of a distinct type of potatoes to which many varieties belong, is widely different from the Bovee, which is likewise representative of another type or family. It is almost impossible to cause the Carman to crowd in the hill, from the planting of a single seed piece, no matter how large. A whole tuber of good size may produce but two or three strong stalks, while had that same tuber been divided into one- or two-eye pieces each piece would likely have produced an equal number of strong shoots. It can hardly be said that the buds or eyes of the Carman lack vigor, but it is true that there is a tendency for a good percentage of the eyes to remain dormant in a whole or half tuber when planted, while further cutting of the same tuber—the isolation of each single eye—would have resulted in a full percentage of growth. On the other hand the Bovee represents a class of varieties which may be said to be free and profuse in their habit of sprouting or germination, as has already been demonstrated in the accompanying table.

As to the time of maturity, in the different sections of the same varieties, there seemed not to be a noticable difference, although it has been observed by some experimenters that while plants from whole tubers do not mature earlier in the season, there may be obtained from hills grown from whole tubers new potatoes of usable or marketable size earlier in the season than from piece planting.

The following table presents, in a form convenient for comparison, the average results of two years' experiments (1906-1907) with different quantities of seed potatoes per acre. The test of small tubers, as noted in the table, was included only in the test of the second season (1907). The addition of this test of small tubers was and is considered a feature of but minor importance. The figures are given only as a matter of interest.

It will at once be noticed that with the Bovee the yield of small or "unmarketable" tubers (tubers less than two ounces in weight) increases quite uniformly as the size of the seed pieces and quantity of seed per acre are increased. This is not apparent with the Carman, clearly for reasons already given with reference to the Carman's peculiar nature or habit of restricted sprouting or "germination."

TABLE SHOWING RESULTS OF USING DIFFERENT QUANTITIES OF SEED POTATOES PER ACRE. AVERAGE FOR TWO YEARS

Yield per acre, bus.			50	100	150	200
Bovee (one eye)	10 bushels per acre marketable	146.6				
	unmarketable	32.7				
Bovee (two eyes)	15 bushels per acre marketable	159.1				
	unmarketable	45.5				
Bovee (half tubers)	25 bushels per acre marketable	131.7				
	unmarketable	73.5				
Bovee (whole tubers)	40 bushels per acre marketable	168.7				
	unmarketable	99.4				
Bovee (small or 2 oz. tubers)	22.6 bushels per acre marketable	150.1				
	unmarketable	73.5				
Carman No. 3 (one eye)	10 bushels per acre marketable	164.2				
	unmarketable	25.1				
Carman No. 3 (two eyes)	15 bushels per acre marketable	204.3				
	unmarketable	31.7				
Carman No. 3 (half tubers)	25 bushels per acre marketable	217.1				
	unmarketable	35.7				
Carman No. 3 (whole tubers)	40 bushels per acre marketable	223.0				
	unmarketable	51.8				
Carman No. 3 (small or 2 oz. tubers)	22.6 bushels per acre marketable	145.2				
	unmarketable	48.2				

Upon a basis of dollars and cents, we find that the Bovee, at the fair, average price of 50 cents per bushel both for the seed used and the product grown:

15 bushels of seed per acre gave a gain of \$ 3.75 over the 10 bushels.

15 bushels of seed per acre gave a gain of 18.70 over the 25 bushels.

15 bushels of seed per acre gave a gain of 7.70 over the 40 bushels.

With the Carman No. 3, at the same price per bushel:

15 bushels of seed per acre gave a gain of \$17.55 over the 10 bushels.

25 bushels of seed per acre gave a gain of 1.40 over the 15 bushels.

15 bushels of seed per acre gave a gain of 3.15 over the 40 bushels.

In these calculations the value of the *excess* of seed, where the larger quantities were used, was of course taken into consideration.

There yet remains a very important feature to be explained which the foregoing table does not exhibit. This matter pertains to the size, uniformity and beauty of the tubers; these qualities figure largely when the product goes upon the market—especially a dis-

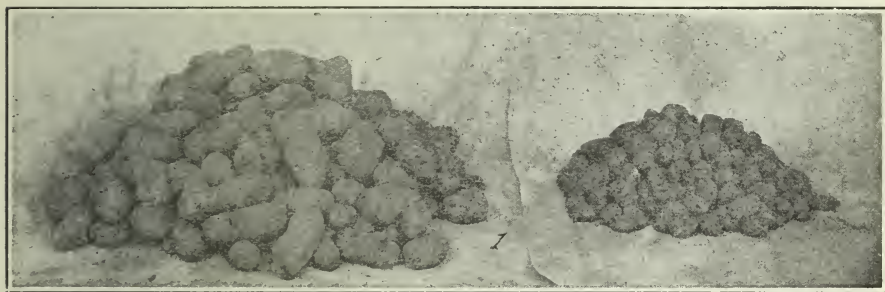


Fig. 4. Bouee. Product of seeding at rate of 10 bus. per acre—one-eye seed pieces.

criminating, retail market. In every case the tubers grown from the one- and two-eye seed pieces, while somewhat less in number, average far above those grown from the heavier rates of seeding. For the cause of this we have only to refer to the table showing the proportionate increase of the number of stalks or plants per hill as the quantity of seed per acre is increased by using larger seed pieces. It becomes

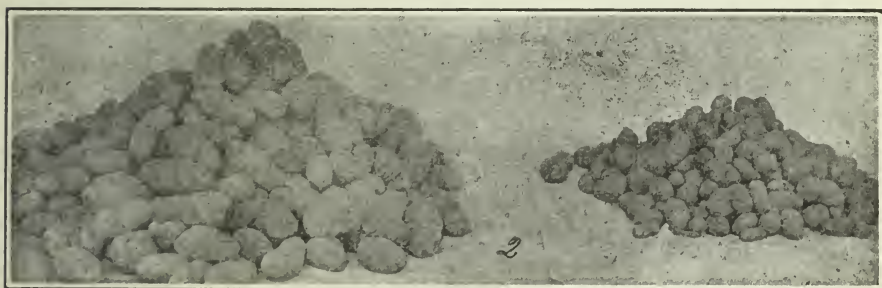


Fig. 5. Bouee. Product of seeding at rate of 15 bus. per acre—two-eye seed pieces.

clear that a surplus potato stalk in a hill of potatoes is just as a surplus stalk of corn in a hill of corn; it is a “weed plant;” and while its presence may or may not lower the total yield, in weight or bulk, of the hill in which it occurs, its presence will detract from size, the fullest development and sightliness of the individual tubers produced in that hill. The photographs which follow show conclusively that the

quality of the product declines as the rate of seeding per acre increases, even though the scales and the bushel measure may indicate a greater or lesser increase in the total weight or bulk.

Inasmuch as whole, small or two ounce tubers were used in 1907 in comparison with the one- and two-eye seed pieces and the half-tubers and whole tubers (all from select stock) it will, perhaps, be

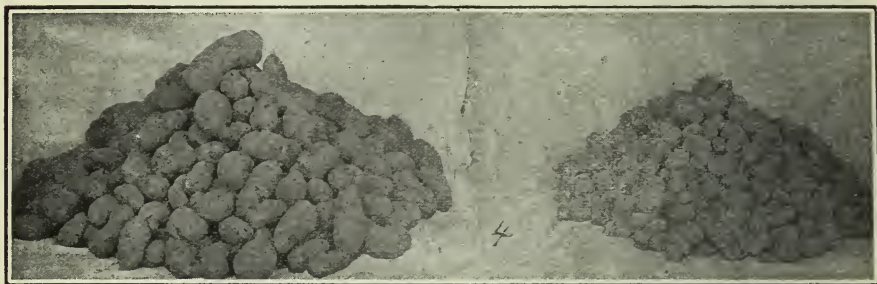


Fig. 6. Bovee. Product of seeding at rate of 25 bus. per acre—half-tuber seed pieces.

well to include a brief statement relative to results. For reasons which will be made clear in the chapter on potato seed selection and improvement, the writer does not care to spend much time with small tubers as a basis of experimental work with potatoes, nor valuable space in discussing them. However, it has been urged by some growers (and it is true) that small potatoes used for seed



Fig. 7. Bovee. Product of seeding at rate of 40 bus. per acre—whole tubers for seed.

materially cuts down the expense of crop production, because of such stock not being marketable—because it would otherwise represent a by-product, a waste, a loss in the business of the market grower. Certainly economy in every industry is to be commended and encouraged so long as such economy does not foster a menace for the future. So long as the grower produces stock for a market

that caters solely to the country's food supply and chooses to use the culls, the screenings, the chaff of his successive crops for seed we can hardly object; but when he repeatedly uses such seed stock and disposes of his product to seed dealers who distribute it far and wide as pure, well-bred, high-class seed stock, the thread of truth, honor, discretion and safety is strained wellnigh to, if not beyond the breaking point.



Fig. 9. Carman. Product of seeding at rate of 15 bus. per acre—two-eye seed pieces.

Small seed potatoes, planted whole, often produce as great a bulk of tubers that can be passed into the marketable grade, as piece-planting of good sized tubers; but, taken as a whole, the character of the marketable stock grown from small tubers is far below that produced from one- or two-eye pieces of larger and uniform seed stock.



Fig. 8. Carman. Product of seeding at rate of 10 bus. per acre—one-eye seed pieces.

These results have been observed again and again; it needed no field test to prove what has been seen year after year in various sections. Therefore, as was anticipated, just such results were found very marked in the test plots of 1907. The marketable quantities from the small seed tubers compared well with the marketable quantities from the different rates of seeding from large tubers, but the aver-

age size of the tubers that composed the marketable product from the small seed was very noticeably inferior to the product of one- and two-eye pieces of the same varieties grown in adjoining plots, while

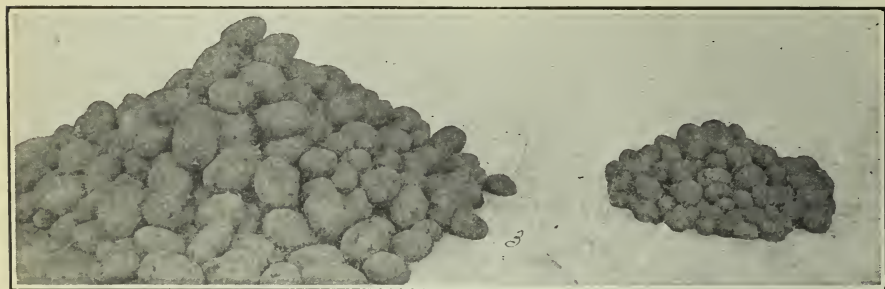


Fig. 10. Carman. Product of seeding at rate of 25 bus. per acre—half-tuber seed pieces.

the proportion of small or unmarketable tubers was greater in both Bovee and Carman No. 3 than from any of the rates of seeding save that of 40 bushels per acre where the large, whole tubers were

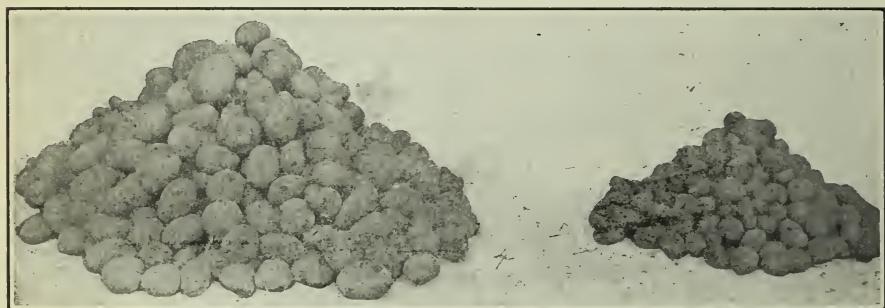


Fig. 11. Carman. Product of seeding at rate of 40 bus. per acre—whole tubers for seed.

used. The crowding of the plants in the hill where small, whole seed was used, was but little less than where the whole, large tubers were planted—as might well be expected from the fact that a small tuber contains as many eyes as that same tuber would have contained had it grown to much greater size.

POTATO SEED SELECTION AND IMPROVEMENT. TUBER ROW AND HILL-ROW TESTS

By far the greater number of new varieties of potatoes originate as seedlings; this is true also of most varieties of vegetables, fruits and cereals. Many potato growers insist that a variety possesses a fixed character; that its attributes—excellent, mediocre or inferior—are determined for all time at its origin, its birth; that it remains absolutely unchangeable so long as it is, through the exercise of proper care, propagated and perpetuated in purity. Certain others

maintain that even though a variety possess all the qualifications of an ideal potato at and immediately subsequent to its origination it will, as time passes, gradually decline in vitality, prolificacy and quality until it is no longer of value; that it will, to use a common phrase, "run out." Still others, and in this class are included our practical and scientific plant breeders, recognize the fact that there are no duplications in nature; that no two plants of the same variety, divisions of the same plant, or buds of the same division are absolutely identical either in physical construction or power to reproduce. Each plant, division, branch and bud possesses an individuality which renders it more or less different from others of its kind. This is termed *natural plant variation*. Such variations, it is true, are usually so slight, so generally unnoticeable, as rarely to attract attention from the casual observer; but there are no set boundaries, no marks of limitation, within which the individuality of a plant may safely be declared to assert itself. Nine hundred and ninety-nine plants of a certain variety may be stamped each with its own peculiar though perhaps well nigh inscrutable personality, while the one-thousandth individual may manifest so little regard for family precedent, example or influence as to bound so high above or descend so far below the average of its companions in performance or appearance, or both, as to establish a new record for excellence or utter worthlessness never before approached by an individual plant of that variety. It has, indeed, sprung so far without the usual limits of performance of its parent type as to warrant its being declared a new variety. This greater variation of plants is technically known as *mutation*, though the terms "bud sporting" and "freaking" are commonly applied. To mutation was due the origin of the White Seneca Beauty or *Livingston* potato, which was discovered as a white skinned tuber in a hill of red Senecas—an excellent example of "sporting." Other examples of varieties of fruits and vegetables originating in this manner might be given. If this remarkable breaking away from varietal boundaries has been in the direction of improvement, the new variety will be accorded an appreciative reception at the hands of the culturists; it will become widely known and profitably grown. If, on the other hand, the extreme variation brings with it only inferiority as compared with the original, average or parent type (which is more often true) it may well be lost to cultivation, as it surely will be.

Therefore, through extreme bud variation or mutation may a new variety be born as truly as from seed. Likewise, through the lesser, though still clearly marked mutations, may a variety improve or degenerate without losing its identity with the parent variety; and it

is upon this natural variation of plants—even the lesser variations—that the plant breeder bases his reasonable hope of success in the betterment of already standard and favorite varieties, by selection of such strains as give promise of retaining the desirable and eliminating the undesirable characteristics of the original type. Such improvements are already accredited to not a few of our thoughtful careful, potato breeders.

We have, then, in view of the fact of universal plant variation, to unlearn the old adage that “like begets like.” Instead, at the very outset of our effort to improve varieties by selection, let us assure ourselves that, as a rule and at best, similarity begets similarity; that a variety is composed of a great number of strains; that the older a variety may be the greater will be this multiplication of strains, that these multitudinous strains will represent all gradations of value from the superior to the inferior, yet possibly all be sufficiently similar to the original type to justify us in maintaining that the variety is pure.

What would be the result, therefore, of separating the superior strains of a variety of potato, as represented by perfectly formed tubers from high-yielding hills, from the commonplace and inferior and planting these separately? The yielding power, uniformity and appearance of that variety would at once show marked improvement. On the other hand if the inferior strains, as represented by the small, imperfectly formed tubers from low-yielding hills, be separated from the superior strains and used for seed, the yielding power will be reduced and the uniformity and appearance will exhibit marked deterioration.

It is for the purpose of separating the superior from the commonplace and inferior that the several plans for selection of seed stock have been devised. Let us carefully note at least two of these schemes:

It often happens that the interest of the potato grower in potato seed improvement is awakened only at or near the time of planting. His only recourse at such a time is to choose his seed from the bulk or “bin” of the storage. This plan is open to well founded objections as compared with choosing seed stock from individual hills in the field at the time of digging, but it is vastly more to be commended than failure to choose at all. Let us see wherein lies the weakness of selecting even the choicest appearing tubers from the bin or bulk. It is evident that the planter will accept only those specimens which appeal to him as representative or typical of the variety with which he is concerned; they must be smooth, uniform and bear indications of vitality as evidenced by soundness and well-developed eyes. But

he has no means of determining whether a tuber answering these requirements in appearance was *one of several similar ones* in a high-yielding hill, or the *only one* of its size in a low-yielding hill. It would really be to his future interest and profit to separate these strains, retaining the prolific and discarding the unproductive. The tuber-row-test will prove this point and he will proceed as follows:

Cut each of the selected tubers to uniform, one-eye pieces. It is not difficult to find tubers of almost any variety that will each afford ten such seed-pieces; but let the number of seed-pieces from each selected tuber be such that the test rows planted from each will be uniform in length and number of hills. Plant these tuber-test-rows with one seed-piece to a hill, the hills 16 inches apart and marked with a numbered stake driven securely in the ground, on as nearly uniform soil as can be chosen. Give the same care in the way of fertilization, cultivation and spraying to all the rows composing the tuber tests. There is no limit to the number of tuber rows which may thus be included in the trial plot; but it is a significant fact that the greater the number of tubers thus planted the greater will be the number of striking variations sure to be exhibited both in habit of growth of the plants and in yields; and also the more extended will be the opportunity of obtaining a number of superior strains of the variety being studied. At digging time the product of each test-row should be weighed and the weight as well as the general characteristics of the product carefully compared with those of its companion rows. The more excellent lots may be distinctly labeled by numbers and kept in separate crates for a second trial upon a more extended scale; or, if but one season's trial be all that it be desired to make, the superior yielding strains may be thrown together, thus forming a composite seed lot to be planted the following season in comparison with ordinary or unselected stock. This is not recommended, however, in careful potato selection; the isolation of separate strains should be maintained until the one superior strain is determined by repeated tests. The second season's test should be in duplicate—that is, one-half the seed of a certain tuber-product should be planted in Row No. 1 in Section A, and the other half in Row No. 1 in Section B in another part of the field or area. Average results in yield under different conditions are thus obtained from each strain.

The ideal method of inaugurating an experiment in potato seed selection is to make the original selection in the field at the time of digging the crop. Several hundred hills should be dug in a representative portion of the field, each hill being thrown by itself. After the separate hill products are thus exposed a careful selection of individual hills should be made, choosing only such hills as contain

a satisfactory yield of uniform, marketable tubers which are typical of the variety to which they belong. It is well to keep in mind that a hill of potatoes may be good because it is inherently good, or it may be good because of certain conditions of the soil or of other environment which have affected that hill alone. A few small tubers in a hill should be no objection to the choosing of that hill, providing that hill contains a liberal yield of good, representative, marketable tubers. Each hill chosen should be bagged separately and numbered consecutively. Muslin bags are preferable, though strong, paper bags may be made to answer. The muslin bags are superior because the hill selections contained therein can not only be readily and safely stored in covered, mouse-proof barrels, but at planting time the seed can be treated in the bags with formalin or corrosive sublimate, by throwing the bags of seed into the solution. With paper bags this cannot be done without their breaking and causing mixture of the potatoes.

At planting time from each hill of tubers is cut a certain number of uniform, one-eye seed-pieces. It is quite easy to obtain from an average hill 20 of these seed-pieces. Duplicate test rows, each containing 10 seed-pieces planted one eye to a hill and the hills 16 inches apart, are planted from each parent hill, on uniform soil. As an illustration from parent hill No. 1 are cut 20 one-eye seed-pieces; ten of these single-eye pieces are planted in hill-row No. 1 in Section A; the remaining 10 similar pieces are likewise planted in hill-row No. 1, Section B (the duplicate). Parent hill No. 2 likewise goes to plant hill-row No. 2 in Section A and hill-row No. 2 in Section B. Every fifth or sixth row in both Section A and Section B is planted with good tubers taken at random from bin or bulk, cut to one-eye pieces and so distributed in the various check rows that but one seed-piece from each tuber will be planted in the same check row. Twenty such tubers, each cut to 10 single eye pieces, will suffice to plant 20 check rows of 10 hills each with no two hills in the same check row planted from the same tuber. In detail, "check tuber" No. 1 cut to 10 one-eye pieces may be used to plant hills No. 1 in ten different check rows; "check tuber" No. 2 cut in the same way will go to plant hills No. 2 in the ten different check rows, etc. The object of the check rows is to afford a standard or average made up of composite seed stock, with which to compare the yields from the different rows planted from selected parent hills. The following diagram, the writer trusts, will assist in rendering the plan of a duplicated hill' row test plot readily interpreted.

PLAN OF A HILL-TO-A-RROW TEST FOR POTATES

		Section A										Section B (Duplicate)									
Hill-rows	1	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
	2	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
	3	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
	4	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
	5	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Check-row	1	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
Hill-rows	6	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
	7	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
	8	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
	9	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
	10	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Check-row	2	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o

Well marked results in potato seed selection, as determined by the hill-row test plots, have been secured at the Ohio Station, both in selection for high yields of tubers and for disease resistance of plants. The work was begun under the supervision of Mr. C. W. Waid, in 1903, by selecting:

(1) A series of heavy producing hills of Carman No. 3, regardless of the character of the plants producing such yields.

(2) A corresponding series of hills of the low yielding or common stock of Carman No. 3 for comparison, regardless of the character of the plants producing the same.

(3) A series of hills of Whiton's White Mammoth, the plants of which exhibited marked resistance or immunity against blight, which was prevalent in the field in 1903.

(4) A corresponding series of hills of Whiton's White Mammoth the plants of which were destroyed by late blight in the season of 1903.

Records of yields from individual hills and their progeny, of these various lots, were secured by Mr. Waid during the seasons of 1904-5-6, all individual hill products being kept separate during that time. In the spring of 1907 the writer was given charge of the work and the now great number of selected seed lots for the purpose of determining, under field conditions, what had really been gained by the original hill selection and the great amount of painstaking work of the succeeding three years. The first move in the enlargement of the scope of the work was to take from the hundreds of separately preserved hill-lots of seed:

(1) Seventy representative hills of the high yielding strains of Carman No. 3, which weighed in total, 94 pounds.

(2) Seventy representative hills of the lower yielding or common strains of Carman No. 3, which weighed, in total, 36 pounds.

Composite seed lots were made by mixing together the 70 hills of high-yielding strains; also by mixing together the 70 hills of low yielding strains or common stock. Sufficient seed was taken from these two separate lots to plant four rows of the high-yielding strains and two rows of the common strains for comparison. Care was exercised to have the tubers of the respective lots as uniform in size, form and appearance as could be selected. This accounts for the unequal number of rows planted, as from the 70 hills of the common strains there could not be found a sufficient number of tubers that would grade up to the required standard of size to plant four rows, or the number planted from the high-yielding strains. This fact in itself is a significant one and quite suggestive of the trend of results of the years 1904-5-6.

The following table exhibits the results of the field test of the selected and unselected Carman No. 3 for the year 1907. The rate of yield in bushels per acre was calculated upon a corrected or uniform stand of plants (or hills) per row:

	Row	Hills	Marketable Lbs.	Unmarket- able Lbs.	Total Lbs.	Rate of yield per acre-Bus.
Selected strains	1	154	136	13	149	175.5
	2	171	151	10	161	170.5
Common	3	155	105½	11½	116	136.3
Selected strains	4	181	182½	8	190½	190.9
	5	168	162½	13½	176½	190.5
Common	6	172	76½	14½	91	96.0

Average per acre in total yield, selected strains, 181.9 bushels.

Average per acre in total yield, unselected strains, 116.15 bushels.

A similar though still more extensive field test was conducted in 1907, comparing the blight resistant strains of Whiton's White Mammoth with the non-resistant strains of the same variety. Comparisons of these resistant and non-resistant strains had been carefully carried on during the seasons of 1904-5-6., by Mr. Waid, just as had been done with the high yielding and common stock of Carman No. 3, all individual hill products being kept separate during this period. In 1907 composite seed lots were made up by throwing together and mixing the hill-product of the resistant strains; likewise the non-resistant strains. A plot of 12 rows was planted, embracing 8 rows of the resistant and 4 rows of the non-resistant stock. The following table shows the result of the field test, The rate of yield per acre is based on a corrected stand of plants or hills per row:

	Row	Hills	Marketable Lbs.	Unmarket- able Lbs.	Total Lbs.	Yield per acre Bus.
Resistant	1	168	183	15	198	213.8
	2	175	179½	12	191½	198.1
Non-resistant	3	170	99½	15½	114½	122.5
Resistant.....	4	167	168½	14	182½	198.0
	5	162	178	15	193	200.6
Non-resistant	6	188	154	20	174	167.8
Resistant.....	7	174	188	14	202	210.5
	8	168	162½	17	179½	192.0
Non-resistant	9	171	140	15½	155½	164.9
Resistant.....	10	176	207	12½	219½	226.3
	11	168	182½	10	192½	207.6
Non-resistant	12	176	137½	16½	154½	158.9

Average yield per acre, disease resistant strain, 206.9 bushels.

Average yield per acre, disease non-resistant strain, 153.5 bushels.

The foregoing tables are sufficient to prove, quite within themselves, the value of potato seed selection. However, in addition, the writer is constrained to add that the 1907 field test plots of both Carman No. 3 and Whiton's White Mammoth were object lessons in demonstration of the effects of seed selection the whole season through. The high yielding Carmans, because of their superior vigor, could be distinguished from the common strains, even by a disinterested visitor, as far away as the plot could be seen. Likewise there was a remarkable difference between the rows of resistant and non-resistant W. W. Mammoth. This difference was more and more marked as the close of the growing season approached. The non-resistant rows of plants were quite dead in early September, while the resistant rows continued green, vigorous and growing until cut down by the frost some three weeks later. No spraying for blight was done on this plot as it was strictly a test of disease resistant versus non-resistant plants.

It may well be stated, furthermore, that experiments coupled with many observations suggest that little is to be gained by selection of parent hills of potatoes on the basis of disease resistance of the plants, over selection of parent hills because of the superior, individual yields. It is the actual work done within the hill that should most interest the potato breeder; the more promptly these desired results are accomplished by the plant the more desirable that strain. While, as the latter table shows, good results are obtained by selection of hills because of disease resistance—because of long standing and late growing in the field—it has not been apparent that this cause for selection is to be commended above the plan of selecting for prolificacy in the hill regardless of the character of the plants of

such hills. Indeed selection of long standing, late growing hills or plants should not be done unless blight or other disease is surely known to be present in the field and responsible for the premature breaking down of the majority of the plants; for, through natural variation of plants in which season of maturity as well as other characteristics are affected, there is grave danger of so lengthening the season of growth and development of that variety by choosing these late growing strains, that danger of non-maturity of crops may be thus invited for future years.

Many isolated, late growing hills of Carman No. 3 were dug from a 3-acre field on the Station grounds in the autumn of 1907 and compared with adjacent hills which ripened many days previously. In not a single case was the product of a late growing individual hill found to be greater or better in any way than equally vigorous hills which had more promptly closed their season of growth. Blight was not present in the field, however, and the later growing hills simply demonstrated that there develop, through natural plant variation, these tardy, deliberate, slow-maturing strains which we should not mistake for strains of special disease resistance.

SHALL WE USE THE SMALL POTATOES FOR SEED PURPOSES?

The question is often asked by potato growers, "What about using the small potatoes for seed?" This subject has already been touched upon in a preceding chapter. It is one of importance not only to the individual potato grower, but to the potato growing industry of our state and country at large.

As a regular practice there is no hesitation on the part of the writer in declaring that the use of the small or cull stock for seed is not to be seriously considered for a moment by the grower who would improve or maintain the quality of his stock. In a word, while the small tubers of a crop may include a *small percentage* of the standard strains composing a variety, it also includes all the worthless trash, all the "chaff" of an unselected variety, developed through years, perhaps decades of plant variation. Let us consider the matter from a simple illustration:

From a block of 1000 hills of common, unselected stock including high, moderate and low yielding strains of a given variety, seed for the succeeding year's planting is to be taken. Let us estimate that 800 of these hills fairly represent the average or moderate yielding strains of the variety; that 150 hills are below the average type—are low yielding strains; that 50 hills are above the average type—are superior high-yielding strains. It is reasonable to figure on this basis, for experiments have repeatedly shown that there is a greater

tendency, through natural plant variation, toward a falling below the average type of a variety than of rising above the same. Now, what would be the character of the seed stock chosen from the 1000 hills by the grower who insists upon careful selection of his seed and would accept only good sized uniform, representative, marketable tubers from the bin or bulk? His choice would include:

(a) A *very heavy*, perhaps almost *total percentage* of the *high yielding strains*.

(b) A *heavy percentage* of the *average or moderate yielding strains*.

(c) A *very small percentage* of the *inferior or low yielding strains* limited to the occasional tuber that would grade up to the required size and form.

Upon the other hand what would be the character of the seed stock used by the grower who insists upon selling the marketable tubers and retaining the small ones for planting? His choice would include:

(a) A *very insignificant percentage* of the *superior or high yielding strains*.

(b) A *small percentage* of the *moderate yielding strains*.

(c) A *very heavy, almost total percentage* of the *low yielding or inferior strains*.

The persistent use of small seed year after year can have but one result, the rapid deterioration of the variety thus perpetuated by the steady, certain process of elimination of all the good and superior strains of that variety. Growers who practice this plan of "seed saving" and dollar saving(?) are persistent in their theory that varieties of potatoes "run out;" and they offer their personal experience and their crops in support of their theory and as evidence that they are right in their conclusions.

There are, however, certain conditions under which, for a time at least, the smaller tubers (not culls) may be used with good results. It is subsequent to a thorough course of selection in which there has been a "weeding out" of the inferior strains. A tuber may be small because of crowding in the hill with larger tubers; or it may be small because of some unfavorable condition under which it was forced to exist; these, if they be of selected strains, ought to give satisfactory results when used for seed. It is the small tuber that is small because of *inherent inferiority* to which objection may be justly urged. However, at the same time of using these smaller tubers for seed there should be in progress a continuity of seed selection with the purpose in view of gradual, constant improvement of the variety or varieties which have been accepted as the most

profitable for local or special requirements. The land owner who insists upon placing the cream of his farm crops upon the market and using the "skim-milk" product for the basis of succeeding crops is progressing only toward well merited defeat which will be met sooner or later. The choicest of the crop is none too good for seed purposes.

PLANTING AND CULTURE

In a preceding chapter have been discussed approved methods of preparation and fertilization of the soil for potatoes. Thorough preparation renders planting a comparatively easy and agreeable task—especially where the land is level, or nearly so, and a modern horse-power planter is used. For the general crop the rows should be spaced three feet apart and the seed pieces dropped from 14 to 16 inches in the rows. The more dwarf growing plants of some of the first early sorts may allow of spacing the rows at 30 inches and dropping the seed pieces 12 inches apart, though this close planting is not recommended for the stronger growing varieties. The machine should be adjusted to deposit the seed pieces at least four inches below the level of the surface of the ground. Most planters cover the seed in such a way as to leave a little ridge over the rows, beneath which the seed pieces are probably covered something near six inches in depth. After the seed has sprouted well and the young shoots are approaching the surface of the ground, the field may be gone over with a weeder or a fine smoothing harrow in which the teeth slant backward, levelling the ridges and leaving the surface smooth, even and mellow. A second and even third cultivation may be given with weeder or harrow by the time the little plants are beginning to show well in the rows. These early cultivations save much work later on, as millions of weed seeds are germinated and the tiny plants are killed before they have become established.

On rough, steep ground or on small areas where a horse planter is not practicable, the ground may be furrowed with a large-bladed, single-shovel plow, as described in a foregoing chapter. The furrows should be deep and broad even if it should require two or three passages with the shovel plow to complete them. The rows should always be across the slope of the hill—never up and down the slopes where it is possible to avoid it. By holding the plow firmly the loose soil will be thrown out on either side—a part of it rolling back into the furrow as the shovel of the plow passes, leaving three or four inches of loose soil in the bottom of the furrow upon which to drop the seed pieces. The fertilizer, as before stated, should be applied over the bottom and sides of the broad furrow before dropping the seed, where hand work is done. The rows are spaced and the seed pieces dropped the same distances apart as when planting with a machine.

The seed may be covered either with a hand hoe or shovel plow. If the ground be not too full of stones or sods or roots, the plow will do very good work when run on either side of the open furrow at the proper distance to fill it with mellow soil. The plot should be run over with a weeder or fine tooth harrow when weed seeds begin to germinate, as described for a machine planted field.

The after cultivation is done with a narrow-hoed or "spike-toothed" cultivator, keeping the surface of the ground as level as possible, mellow and free from weeds throughout the growing season. The crust of the soil, after rains, should be broken up as soon as the ground is dry enough to work, and a fine "soil-mulch" maintained on the surface as long as it is possible to drive between the rows with the cultivator without pulling out or breaking the tops of the plants. The maintenance of the "dust mulch" is a sort of insurance against the effects of dry weather; and fine crops of potatoes have been grown by this careful, persistent cultural work even in seasons of serious drought.

The old plan of "hilling up" the rows of potatoes, leaving a high, sharp ridge, is quite unnecessary, and, in fact, is detrimental to the success of the crop should the latter part of the season be deficient in rainfall. Sufficient soil should be worked toward the rows with the cultivator, to insure that the new tubers may not be exposed to the sun; but the surface of the soil should be kept practically level the season through so that the entire area may uniformly receive, absorb and retain the rainfall.

SPRAYING FOR INSECTS AND FUNGUS DISEASES

The spraying outfit is coming to be regarded as an important factor in the equipment of the potato grower. There are many excellent sprayers made; in fact so many firms are engaged in making spraying machines—there is so much competition—that a sprayer necessarily must come up to a reasonable standard of efficiency in order to be recognized on the market. For small plots of potatoes for family use, as well for general use about small grounds and the kitchen garden, there is no form of sprayer more convenient, effective and satisfactory than the small, compressed-air outfit. This consists of a strong, air-tight tank, preferably constructed of heavy, sheet brass, fitted with an air-pump for compressing the air. These tanks are about four gallons in capacity. In use three gallons of spray mixture are filled in the tank and the remaining space of one gallon pumped full of air to a high pressure. The compressed air forces the liquid out through the nozzle in a fine mist. As the pressure becomes too low for effective work through continued spraying, a few strokes of the air-pump again fills the vacant space in the tank

with compressed air. Two or three short pumpings will suffice to force out the contents of the tank. Such outfits are easily carried about with a strap over the shoulder, while the addition of a few feet of light, brass extension pipe, connected to the hose, enables the operator to spray a limited number of young fruit or ornamental trees of considerable height.

For field use in potato spraying, a horse power outfit will be necessary. These, of various styles, are constructed to spray from four to six rows at a single passage, making rapid work in combating the insect and fungus enemies of the potato plant. The traction geared potato sprayers are preferable to those fitted merely with hand pumps, as one man to drive the team is all that is required in the field. However, excellent four-row sprayers can be made by any one who has a good, barrel spray pump and is handy with plumbers' tools. Such a barrel outfit may be placed in a wagon or cart and carried through the field, employing one man to drive and another to pump.

The nozzles on potato sprayers should be adjustable to different widths of rows, and only such nozzles should be used as will apply the liquid with considerable force directly downward upon the plant and in a fine mist or fog-like spray. Mere sprinkling will not suffice where fungus disease is to be effectually combated.

Spraying should begin on the early varieties as soon as the plants are from 6 to 8 inches in height, using a combined mixture that is both a fungicide and an insecticide. Early blight and Colorado beetles are thereby combated at the same time. Spraying should be repeated every ten days or two weeks.

The later varieties or "general crop" may likewise be protected, special care being given to spraying with Bordeaux mixture for the late blight during the month of July. The insecticides may readily be combined with the Bordeaux mixture (fungicide) when the presence of the larvae of the Colorado beetles render an insecticide necessary. The black or "blister beetles," so destructive in certain sections and so difficult to effectually combat with poisons, become sadly discouraged where Bordeaux mixture is freely used and leave the potato field if there be other vegetation in the vicinity upon which they may subsist. The formula for making Bordeaux mixture is given below:

BORDEAUX MIXTURE

Copper sulfate (blue vitriol)	4 pounds
Fresh lime	5 pounds
Water	50 gallons

Where Bordeaux mixture is needed for different sprayings during the season much time and inconvenience may be saved by making up a "stock solution" of copper sulphate; this stock solution will keep indefinitely without deterioration. To make the stock solution use a good barrel (a kerosene, vinegar or whiskey barrel serves well). After removing one of the heads fill the barrel to within 6 or 8 inches of the top with water, measuring the water by gallons. Weigh out in a burlap bag, as many pounds of copper sulphate as the number of gallons of water contained in the barrel. Tie the bag with a strong twine close down to the contents, leaving a loop through which a stick may be thrust. Suspend the bag of copper sulphate in the water by resting the stick across the top of the barrel, in such a way that the bag will be but partially submerged in the water. The material will dissolve much more quickly when held near the surface of the water than when poured loosely into the barrel or suspended near its bottom, as the copper charged water is heavier than the clear water and sinks to the bottom in the form of a saturated solution which no longer has the power to dissolve the substance with which it is laden. When the content of the bag is dissolved each gallon of the water in the barrel will contain one pound of copper sulphate. It is well to slightly stir or agitate the solution previous to measuring out a portion for use.

Bordeaux mixture: Pour four gallons of the stock solution (4 pounds copper sulphate) into the spray barrel and add water to this until the barrel is half filled. The copper solution must be weakened thus before adding the lime or a curdled mixture will result. Weight out, in a bucket, 5 pounds of fresh hydrated lime (known also as "builders' lime," "flour lime," "sack lime," etc.). Add water to the lime, stirring vigorously and pouring off the "milk of lime," or thin white-wash into a second vessel until all the lime is dissolved. Strain the milk of lime, diluted still further with water, through a fine meshed brass wire strainer into the dilute copper solution in the spray barrel, churning vigorously as the lime is being added. A clear bright blue mixture should result. Add to this mixture whatever poison it be desired to use for the destruction of insects and finish by filling the barrel with water.

INSECTICIDES

Arsenate of lead: This is a commercial preparation, as generally used, and one of the most lasting and effective known at the present time, as it is very adhesive. It comes to the buyer in paste form in different sized cans, buckets, kegs or barrels. For one barrel or 50 gallons of spray mixture weigh out, in a bucket, 3 pounds of

arsenate of lead. Add a little water and stir and beat vigorously until a quantity of "milk of lead" is formed. Pour this off into a second vessel or through the strainer into the spray barrel as the paste is dissolved. The lead is slow to dissolve, but by repeatedly adding water, stirring and pouring off it will soon be reduced to milk of lead. Arsenate of lead will not injure foliage, even if used without lime.

ARSENITE OF SODA

Commercial white arsenic	2 pounds
Carbonate of soda	4 pounds

Boil the arsenic and carbonate of soda together in one gallon of water until a clear liquid is formed (15 minutes of brisk boiling will usually suffice). Dilute this solution to 2 gallons by adding water. Pour into a two gallon jug or other vessel that may be securely covered and label "Poison." Use one quart of this stock solution to 50 gallons of spray mixture. If not used in Bordeaux mixture add 5 pounds of lime to insure against burning of foliage.

PARIS GREEN

Paris green	8 ounces
Water	50 gallons

Paris green may be used in the Bordeaux mixture without danger of injury to foliage. If used without combining with Bordeaux add 5 pounds of lime to the barrel of solution.

Lime for spraying purposes: A word should be added regarding the kinds of lime recommended for spray mixtures, as much confusion and misunderstanding exist among beginners in spraying. Fresh burned, lump lime or "stone lime" cannot be excelled for spraying purposes, but many times and in many places cannot be obtained in the desired state of freshness; hence the hydrated or sack lime has come into quite general use. Stone lime, too, requires slaking, and unless a considerable quantity be slaked at a time and this held in reserve as a "stock supply," several purchases as well as several slakings will need to be made during the spraying season. It is always best to buy a quantity at the first of the season, slake it all at once and preserve it in paste form for use. In order to prepare for spraying in this way, weigh out say 50 pounds of good, sound lumps. Slake these in a shallow box by adding water and stirring well to prevent burning. Continue to add water and stir until a smooth paste is formed. Level this paste down in the box and when it is well settled mark the surface off into ten squares of uniform size. Each square will contain what was formerly 5 pounds of lump lime. Cut out and use one square for each 50 gallon barrel of spray mixture. Keep the paste at all times covered with water to prevent drying out.

Hydrated or builders' lime can usually be purchased of most dealers in lumber or building materials. It is put up in air-tight sacks and will keep in good condition a long time if kept in a dry place. This is a very convenient form of lime for the sprayer, as no slaking is necessary. However, it is well to use a little excess in weight over that recommended for the stone lime, therefore 6 pounds of hydrated lime is used for each barrel of 50 gallons of Bordeaux mixture. The writer has used only the hydrated for the past six years with quite satisfactory results.

A PRACTICAL CLASSIFICATION OR GROUPING OF VARIETIES OF POTATOES

The Ohio Experiment Station has tested hundreds of varieties of potatoes and is yet continuing this work. Reports of these tests may be obtained by application, free of cost. Many new varieties are constantly being offered by originators, introducers or dealers, in different parts of the country. A few of these prove of value; an occasional one is excellent; many are quite inferior to our already well known and standard kinds. It is not the purpose of the writer to embody a descriptive list of varieties in this cultural treatise.



Fig. 12. Variety test of potatoes.

Such a chapter would need revision many times over before the chapters dealing with cultural methods should lose their value through evolution or modification of approved and dependable methods of the present day. The question of varieties, too, is one that cannot be treated in a general way with equal benefit to all potato growers. Each grower must determine for himself those varieties which do best under his particular conditions of soil and climate, and use his own judgment in retaining the choicest of these for home use or

market, or both. It is advisable, however, for each grower to test the more promising of the newer kinds grown and reported upon by the experiment station of his state. He may thus find one or more varieties which would prove to be more profitable or excellent in quality than the kinds he has been growing for market or table use. The writer has visited certain sections of Ohio in which the same variety has been grown for perhaps ten, fifteen or twenty years, and this without any particular care in selection and improvement of seed stock. The newer varieties of superior value are unknown—perhaps unheard of.

It has been remarked by certain growers, too, that it is well nigh useless to buy new varieties; for, in many cases, they declare, the alleged new variety proves to be only an old sort renamed and sold at a fancy price. This position tends to confusion and misunderstanding and often unjust criticism of originator, introducers and dealers in pure seed stock. True there are cases in which old varieties may have been reintroduced under new names—we are aware of a limited number of such cases—but such deception is more rare than general. Usually the confusion of growers is occasioned by the fact that there are several distinct types, families or groups of potatoes and that the hundreds of varieties of different origin may be classified in these several groups. Indeed there are many varieties of separate and distinct origin which follow a single type so closely as not to be readily distinguished from each other either by habit of growth of plant or character of tubers, even by an expert potato specialist.

To present in completeness and with absolute accuracy the lists of varieties belonging to the various groups would tax the most careful student of botany. Such exact classification is neither necessary nor advisable in a purely practical treatise of this kind. In the following classification the writer has not only reduced the groups to the least possible number, but mentions only a few of the many varieties which might easily be included in each one. The classification is based principally upon similarity of the character of the tubers of the different varieties, without special consideration of the similarity of the plants of each. In many cases, however, there is a similarity of plants as well as of tubers.

The Triumph Group: round, white, red or mottled; first early. Bliss Red Triumph (known also as Stray Beauty, Strawberry and Bermuda red.

Bliss White Triumph	Noroton Beauty	Nott's Early Peachblow
	Woods' Earliest	

The Early Market Group: Round or oval, flattened; white or slightly tinted; very early; good quality—much superior to the Triumph group.

Early Market Early Standard Early Petosky Irish Cobbler

Early Ohio Group: very similar to Early Ohio in various ways.

Early Ohio Early White Ohio Early Six Weeks
Baker's Extra Early Peck's Early Acme Ohio Junior

Early Rose Group: long or oblong, cylindrical or flattened; pink or white or mottled.

Early Rose Early Roser Mountrose Northern Star
Early Fortune Early Bovee Early Sensation
Early Norther Algoma Miller-Brooke Early Breakfast (white)
Early Michigan (white)

Green Mountain Group: oblong to long; somewhat irregular in form; usually white or straw color.

Green Mountain Whiton's White Mammoth Gold Coin
Ionia Uncle Sam Washington Happy Medium
American Giant State of Maine

Seneca Beauty Group: long or oblong, smooth; small, very shallow eyes; red, pink, or white with pink eyes; quality excellent.

Seneca Beauty Livingston (White Seneca Beauty) Piqua Chief
Pat's Choice

Rural New Yorker Group: round or oval, much flattened; few shallow eyes; color usually white; quality variable.

Rural New Yorker Rural Russet Banner Carman No. 3
President Roosevelt Prosperity Sir Walter Raleigh
Ohio Wonder Green's No. 21 White Giant World Wonder

SEASONAL REPORT ON POTATOES, 1909

By JOS. H. GOURLEY

An interesting and instructive feature of the season's work for 1909 was a further study of the results of sprouting potatoes in sunlight before planting.

The results given in the table below show that it is better to take extra pains to drop the pieces in the furrow sprout end up. The first row was dropped with the sprouts up in each case, the second row with the sprouts down, and the third at random, irrespective of the position of the sprouts. The second series is a duplication of the first.

PERCENTAGE OF GERMINATION

	Sprouts Up	Sprouts Down	At Random
First series.....	98%	66%	68%
Second series.....	89%	76%	89%
Average	93%	71%	78%

These results indicate that considerable care is necessary in planting sun-sprouted potatoes, and that if dropped by a planter the work is not likely to be done satisfactorily.

LATE GROWN VS. COMMON SEED POTATOES

Stock which had been raised from sun-sprouted seed, planted in July, 1908, was planted in the fertilizer plots the past year (1909) by the side of common stock, or seed which had been grown in the ordinary way. There are 34 tenth-acre plots in each series of the 3-year rotation, potatoes-wheat-clover. The plots are 272 feet long and 16 feet wide, which permits five rows of potatoes in each plot. The first three rows in each plot were planted with seed tubers from the July planted stock and the other two with the ordinary seed. This method precluded the possibility of any unequal effect upon the various plots by using two lots of seed.

LATE GROWN VS. COMMON POTATO SEED

Rows 272 feet long, hills 15 inches apart, 216 hills per row.

Plot No.	No. of hills per row		Percent of germination		Average yield per row—lbs.	
	Late grown Rows 1, 2, 3	Common Rows 4, 5	Late grown Rows 1, 2, 3	Common Rows 4, 5	Late grown Rows 1, 2, 3	Common Rows 4, 5
1	159	148.5	73	68	74.1	49
2	157	168.5	72	78	46	47.5
3	178.7	159.5	82	73	89	49.5
4	188	163	87	75	74	27.5
5	200.3	171.5	92	79	73.1	52.7
6	199.6	169	92	78	69.8	58.5
7	204	178	94	82	44	21
8	205	175	94	81	112	89
9	205	173.5	94	80	119	73.7
10	196	166.5	90	77	59.1	23
11	213	178.5	98	82	109.5	82.5
12	204.6	199	94	92	116	86.5
13	205	171.5	94	79	36.1	31.2
14	199.3	197.5	92	91	135.1	112.7
15	203.3	178	94	82	126.1	97.7
16	196.6	179.5	91	83	31.1	43.2
17	195.3	173	90	80	78.8	61.5
18	190.6	178	88	82	75.6	54.2
19	198.6	180	92	83	56	47
20	205.3	192.5	94	89	115.1	83
21	201.3	170	93	78	85	70
22	177.3	159.5	82	73	61	31
23	206.6	170	95	78	110.8	76.7
24	196.6	179	91	82	101	98.7
25	192	162.5	89	75	53.8	45
26	189.6	179	87	82	111.1	89.5
27	193.6	175	89	81	114.1	86.2
28	189	166	87	76	64	63
29	200.3	172.5	92	79	126	93.7
30	204	175	94	81	136.5	96.2
31	196.6	155.5	91	71	43	40.2
32	209	185	96	85	154.8	98.5
33	197.3	165.5	91	76	88.6	85.5
34	186.3	143.5	86	66	49.1	33.8
Total Ave.	195.4	172.3	90	79.3	86.4	64.6

The potatoes were all the same variety (Carman No. 3) and were all planted the same day. The plants grown from July sun-sprouted seed appeared nearly two weeks in advance of the others and maintained quite a noticable difference until they were of large size. In fact so noticeable was the difference in the vigor and increased size of the plants that the casual observer would stop and remark and the more interested one would inquire into the details of the method. Many thought that the two parts of the plots were planted at different dates or possibly were of different varieties. Let it be understood that this particular seed was not sprouted but that it was the crop raised from sprouted seed, which had been planted the first of July the year previous. The serious inroads made by the dry rot fungus or fusarium wilt seriously impaired the results, but an examination of the figures given in the table show that the increased yield and higher percent of germination were constant throughout the plots.

A half bushel of potatoes raised from sprouted seed were placed in a closed box in the storage room beside a half bushel raised by the ordinary method placed in a similar closed box. A half bushel

of the same were placed in closed boxes and set in the greenhouse under a raised bed, over winter. In both cases the July planted potatoes kept much firmer and were much slower to sprout than the others.

TREATING POTATOES FOR SCAB

There are several methods of treating potatoes for scab, such as with flowers of sulphur, soaking in formalin solution or corrosive sublimate, and fumigating with formalin gas. The later method is not used as extensively as it should be, probably because the average grower is not acquainted with it. A comparative test was made between soaking in formalin and the formalin gas treatment.

Johnson No. 1 was used in the test, for the reason that it was the most infected variety available. The tubers were nearly covered with scab and as a consequence the treated plots showed far more scab than would be the case if fairly clean seed were used.

The two methods consist essentially in the following details:

Soaking in Formalin: One pint formalin to 15 gallons of water, soak 2 hours. The seed is thrown into a tub containing this solution or placed in wire baskets and suspended in barrels containing the solution. They are then dried and are ready to plant.

Fumigating with Formalin Gas: Three pints of formalin is poured over 23 ounces of potassium permanganate (for each 1000 cubic feet of space) and the potatoes are exposed to the fumes for 24 to 48 hours.

An air-tight room or enclosure is necessary, with all cracks carefully filled in with paper or other material, as the gas is quite penetrating. A large pan or earthen vessel should be used as there is large increase in volume through the chemical action when the formalin comes in contact with the permanganate. The person should leave the room immediately, as the gas is very poisonous.*

The following results were obtained by the two methods:

Treatment of Seed	Percent Scabby Potatoes in Crop		
	Row 1	Row 2	Average
Untreated ..	50.8	66.3	58.5
Soaked in formalin.....	10.8	22.6	16.7
Fumigated	21.0	15.9	18.4

When there is a quantity of potatoes to be treated it would be advisable to use the fumigation method as the figures show practically no difference in the two methods and fumigation requires no

* Formalin can be purchased for 25 cents per pound. Potassium permanganate at 25 to 30 cents per pound.

time or labor on the part of the operator aside from preparing the room or cellar for the work. On the other hand, if there are but few potatoes to be planted the soaking method will probably be more feasible and satisfactory.

EFFECT OF TREATMENT ON VITALITY OF THE SEED

Unfavorable results are sometimes reported from treating seed potatoes for the scab fungus. Recognizing that injury may sometimes result from this practice, but believing it to be the fault of the operator in most cases, the following observations were made during the past season. The rows were 40 rods long and 3 feet apart. Planted April 28th. All treatment refers to soaking in formalin.

Effect of treatment on vitality of the seed:

3 rows	Early Toledo Market.....	Treated
4 rows	“ “ “	Untreated
3 rows	Early Bird.....	Treated
3 rows	“ “	Untreated
1 row	Miller-Brooke	Treated
1 row	“ “	Untreated
3 rows	W. W. Mammoth.....	Treated
3 rows	“ “	Untreated
4 rows	Pres. Roosevelt.....	Treated
3 rows	“ “	Untreated
2 rows	Gold Coin.....	Treated
3 rows	“ “	Untreated

Careful observations were made from the time of germination throughout the season to maturity and in no case was there any appreciable difference in date of germination, percentage of germination or vigor of plants, between the treated and untreated seed throughout the test.

Cases are reported where germination was poor or slow or an apparent lack of vigor in the plants because of treatment but in all cases which we have been able to trace the treatment was longer or the solution stronger than recommended, or there was improper handling of the seed after treatment.

RESULTS FROM THE USE OF FERTILIZERS ON POTATOES

In this experiment potatoes, wheat and clover are grown in a 3-year rotation, each crop being grown every season. The fertilizers are applied to both potatoes and wheat. The table gives the results as computed on the potato crop alone, but the wheat and clover show a further increase, which adds to the total and net profits from the treatment.

INCREASE PER ACRE SECURED FROM THE USE OF FERTILIZERS ON POTATOES, 15
YEAR AVERAGES. YIELD OF UNFERTILIZED PLOTS,
154 BUSHEL PER ACRE

Fertilizing materials and quantities used per acre	Increase per acre bus.	Cost of fertilizers per acre	Value of increase per acre at 40c. per bushel	Net profit per acre	Cost of increase per bushel
160 lbs. acid phosphate.....	14.99	\$1.20	\$5.99	\$4.79	\$.08
100 lbs. muriate potash.....	9.52	2.50	3.80	1.30	.26
80 lbs. nitrate of soda.....	9.08	2.00	3.63	1.63	.22
160 lbs. acid phosphate } 80 lbs. nitrate of soda }	20.79	3.20	8.31	5.11	.15
160 lbs. acid phosphate } 100 lbs. muriate potash }	30.66	3.70	12.26	8.56	.12
200 lbs. muriate potash } 80 lbs. nitrate soda }	12.36	4.50	4.94	.44	.36
160 lbs. acid phosphate } 100 lbs. muriate potash }	24.18	5.70	9.67	3.97	.23
80 lbs. nitrate soda }					
160 lbs. acid phosphate } 100 lbs. muriate potash }	31.71	7.70	12.68	4.98	.24
160 lbs. nitrate soda }					
220 lbs. acid phosphate } 200 lbs. muriate potash }	35.91	11.40	14.36	2.96	.31
160 lbs. nitrate soda }					
480 lbs. acid phosphate } 300 lbs. muriate potash }	35.63	19.10	14.25	8.56	.53
320 lbs. nitrate soda }					
160 lbs. acid phosphate } 100 lbs. muriate potash }	42.26	5.70	16.90	11.20	.13
80 lbs. nitrate soda }					
8 tons yard manure.....	39.31		15.72		

It will be seen that the lowest cost of the increase has been in the use of acid phosphate alone, but this should not obscure the fact that the greatest profit per acre has been secured with a complete fertilizer, and this, notwithstanding the fact that this land is of higher than average fertility—the unfertilized yield of wheat having averaged 26 bushels per acre for the fifteen years—and that clover has been grown every third season.

AN OUTBREAK OF FUSARIUM WILT

Early in the season a pronounced condition of tip burn was noticed both throughout the Carmans in the fertilizer work and in the variety test grounds. Soon correspondence began to show that it was prevalent throughout the state, causing serious loss. There was some early blight accompanying the tip burn but no late blight developed at the Station. The condition grew much worse as the season advanced; the foliage assumed a pronounced yellowing, and the disease was identified by the Botanical department of the Station as *Fusarium oxysporum* Schlecht. or dry rot fungus. Many varieties died in July and August and nearly all varieties died prematurely

The general manifestations of the disease are a check in growth, usually a curling and folding of the leaves, most noticeable at the growing point of the haulm, a decided condition of tipburn on practically all the leaves of the plant, a premature dying of the plant and finally a darkening of the tissue of the tuber at the stem end. It begins by yellowing the woody vessels at the stem of the tuber but finally may work through the whole tissue.

The premature dying of the plant greatly affects the yield and size of tubers. In some places where the disease had an early development the crop was scarcely worth digging.

There is some variation in the susceptibility of varieties but nearly all the standard early and late varieties were attacked to a greater or less degree in the Station test grounds.

This disease is very slightly controlled by spraying except as it promotes a healthier condition of the plant.

In the fertilizer plots the one receiving the largest amount of fertilizers remained green the longest, while the "No fertilizer" plots were very noticeably the first to go down. They were all sprayed and cultivated alike.

The selection of disease resistant varieties and the special selection of resistant plants, combined with an intelligent rotation of crops and proper handling of seed will be factors largely instrumental in fighting the disease. The Station has made numerous tests for resistance to this disease.

The comparative effect of the *Fusarium* trouble on different varieties on August 6th is shown below. Later practically all varieties succumbed to the disease.

CONDITION OF VINES AUGUST 6, 1909

DEAD

Early Petosky*
Early Russet*

Early Standard*
Noroton Beauty

Epicure

BADLY AFFECTED

Cal. Russet*
Clyde*
Early Fortune
Early Johnson*
Early Ohio*

Early Thoroughbred*
Frayer O. K.*
Happy Medium*
Knowles' Big Crop*
Lily White*
May's Late*

Merrill*
Millerbrooke*
White Albion*
Plucky Baltimore*
White Rose

FAIRLY GREEN

Bovee*	Late Hebron	Red Pearle*
Early Bird*	Market Prize*	Noxall
Early Breakfast*	Early Monarch	Norcross*
Early Michigan*	Early Fortune	Kellers Green Mt.
Green Mt.*	White Rose*	New Snow
Ionia Seedling*	Washington*	Pioneer
Johnson's No. 2*	Seedling No. 4	Seedling No. 4
	Rural New Yorker*	

GREEN

Carman*	D. J. Miller*	Prosperity*
S. Com. Violet*	N. Late Nebraska*	Pres. Roosevelt*
Mortgage Lifter*	New Queen*	Planet*
Green's 21*	Banner*	Pioneer
Harrolds' Choice*	White Elephant*	Ohio Wonder*
Johnson's No. 1*	Snow*	New Snow
Late Petosky*	Seneca Beauty*	Late Hebron
Lepas*	Seedling No. 5*	Noxall
Livingston*	Seedling No. 4*	Snowflake
Early Manistee*	Rural Russet*	W. W. Mammoth

* Means that duplicate row was the same.

SIR:—I have the honor to transmit herewith and to recommend for publication as a bulletin of the Station the accompanying manuscript entitled "The Relative Durability of Post Timbers."

This bulletin, prepared by J. J. Crumley, assistant in forestry, during the period when the work was under my charge, is the result of extended investigations in this and other states regarding the relative durability of the kinds of timber most commonly used for posts. One object in going into other states in this work was to get data on some varieties of timber that have not been in use long in this state but are rapidly coming into general use and are very important in this investigation.

So far as known no work of this kind has ever been undertaken on so large a scale. While this fact alone is not urged as a reason for drawing definite conclusions, it may be taken as evidence to establish with considerable certainty the relative durability of the kinds of timber named in the investigations.

The striking variability of wood as to durability under varying conditions makes it plain that the number of observations count for a great deal. On the whole, the results cannot fail to be of value, both as to the facts stated, and suggestions which may be aroused in the minds of readers.

Respectfully,

W. J. GREEN, *Consulting Forester.*

CHAS. E. THORNE, *Director.*

BULLETIN

OF THE

Ohio Agricultural Experiment Station

NUMBER 219

JUNE, 1910

THE RELATIVE DURABILITY OF POST TIMBERS

By J. J. CRUMLEY

The various state Experiment Stations and the Forest Service at Washington are continually receiving inquiries concerning the durability of timbers in the soil. The farm journals throughout the country are also frequently called upon to answer questions on this subject.

In the forestry exhibit at the Ohio State Fair, in 1906, and also in 1909, there was a group of eight specimens of wood labeled "Post Timbers." During the time that these specimens were on exhibition there were six different varieties of wood pointed out with the expression "That is the best for posts." These six were yellow locust, red cedar, hardy catalpa, Osage orange, mulberry and chestnut.

While the data published herein were being collected, men were found living on adjacent farms—one believing very steadfastly that posts should be seasoned before they are put in the ground, the other just as firm in his belief that they should be set green; and again, one believing that posts should be set with the top or

small end in the ground, that is, the opposite to the way they grew in the tree, the other that they should be set with the top or small end up. These men were probably speaking from an experience of many years. Such circumstances may be duplicated over and over. The above and scores of other observations of this kind seem to indicate that there is need of careful and extended investigation along this line.

The time has come when we must make a clear distinction between the qualities of post timbers. Timber is getting more and more scarce and prices keep increasing, and the future purchaser must know what he is buying. Hundreds of farmers in our state are beginning to set out trees. More of them are planting with a view to growing posts than for any other purpose. Surely then we should understand as clearly as possible which timber will produce the most durable post. We should also consider carefully the rate of growth, pests, and adaptability to soil, climate, etc.

The material published in this bulletin has been obtained from the examination of 292 fences containing 30,160 posts. These fences are situated in Ohio, Indiana, Illinois, Kansas and Texas. The counties in Ohio in which fences have been examined are: Warren, Greene, Clark, Guernsey, Adams, Ross, Wayne, Fulton, Montgomery, Champaign, Morrow, Knox, Van Wert, Preble, Williams, Putnam, Union, Miami and Franklin.

The object in going outside of the state was to get data on two kinds of timber, the hardy catalpa and the Osage orange, that have not been used very long in this state, but are very important in the consideration of post timbers. Two summers were spent in the Wabash Valley, the home of the hardy catalpa. Here posts were studied that were cut from trees that grew in the forest. A portion of one summer was spent in Kansas, examining catalpa posts cut from trees that grew in cultivated groves in the Farlington, Hunnewell and Munger plantations. A portion of one summer was spent in Texas, examining Osage orange posts.

In each of these states a few fences of oak, locust and mulberry were examined for sake of comparison, to use as a kind of measuring stick in case the soils or climate might prove more or less severe on posts than in Ohio.

The manner of collecting this material was as follows: A fence of considerable age having been found, usually old enough to contain rotten posts, it was examined closely, the data being taken down on a blank form. One of these forms is given below, filled out.

TABLE I
OHIO AGRICULTURAL EXPERIMENT STATION
DATA CONCERNING FENCE POSTS

November 25, 1906.

Owner Edwin Woods P. O. Lebanon, Ohio

County Warren Township Union

Location 3¼ miles southeast of town. Fence is the east and north sides of the "spring field."

Kind of Fence Board and wire.

Direction N-S and E-W.

Soil Clay loam, rather thin.

Dra'nage Good.

Kind o. Posts Yellow locusts.

Age 20½ years Set in spring of 1886.

Time of Cutting _____

Seasoning Seasoned.

Size of Posts Small to medium.

Distance Apart 8 feet.

Number Sound 126 (81 percent) u s 71 (82½ percent) d s 26 (66½ percent)

Number Rotten 30 (19 percent) u r 15 d r 13

Total Number 156 86 39

Remarks: In case of 31 of the posts it was not evident whether they were set top up or top down.

Posts came from Kentucky. Were made from large trees. Flat bark posts and triangular heart posts are frequent. Posts next to bark show better record than the triangular ones split from center of tree.

These are from same lot of posts as those on the W. and S. side of same field (recorded in Loc. No. 9, 46), which were set one year earlier and have a larger percent of sound posts. Size and selection caused the difference.

The most of these items are taken from the fence itself and its surroundings. "Time of Cutting" and "Seasoning" can not always be obtained. The "Age" is especially important and was in each case obtained with the utmost care.

When the above items were obtained, the fence was then examined post by post and the condition of each was set down in order as indicated in the following table.

TABLE II
OHIO AGRICULTURAL EXPERIMENT STATION
POST TO POST RECORD

(u)—set top up. (d)—set top down. (s)—sound. (f)—fair. (p)—poor. (r)—rotten.
(h)—heart post. (b)—post next to bark. In summary, (f) is classed
with (s) and (p) with (r).

Owner Edwin Wood

Beginning at S. E. cor. of field, go north.

1	ds	ds	us	us	s	s
2	s	dr	us	us	us	ds
3	s	us	us	us	s	dr
4	us	ur	us	ur	ds	us
5	us	dr	us	up	us	dp
6	s	s	us	df	us	us
7	uf	p	ds	ds	uf	df
8	us	us	us	uf	us	Cor. N. W.
9	us	s	us	df	s	
10	us	us	us	ur	ur	
11	us	us	us+	us	ds	ds 26
12	us	us	os	us	dr	dr 13
13	s	us	ds	s	df	39
14	us	us	uf	us	us	
15	ds	r	s	ur	us	us 71
16	us	dr	ds	ur	us	ur 15
17	ds	us	ur	up	ds	86
18	us	ds	us	dr	dr	
19	ur	us	s	ds	us	
20	s	ds	us	uf	us	
21	us	us	s	up	dr	
22	s	s	us	ur	dr	
23	s	uf	us	s	df	
24	s	uf	ds	us	us	
25	f	dp	ds	us	s	
26	s	ds	s	ds	ur	
27	us	us	us	s	dp	
28	s	us	ur	s	us	
29	s	df	uf	s	dr	
30	us	us	us	ds	ur	

+-N. E. Cor.

In this table, each column contains the record of 30 posts. That is, the one at the head of the second column is the thirty-first post in the fence, the one at the head of the third column is the sixty-first, etc. The whole fence contains 157 posts, one of which, No. 72, is oak, leaving 156 locusts to be counted in the summary.

One interesting item that this fence furnishes is the relative condition of posts set with the top down and those set with the top up. Of those set top down, there are just half as many rotten as

there are sound; of those set top up, there are only about one-fifth as many rotten as there are sound. Sometimes a post does not show in which position it has been set. There are 31 of such in this fence.

It will be noticed under "Remarks," Table I, that this fence has a number of triangular heart posts and a similar number of thin, flat posts that have the heart split off. The most of the rotten posts in the fence are found among the heart posts and nearly all of the thin, flat ones are sound. The same feature was found in many other fences, and is true of several kinds of timber.

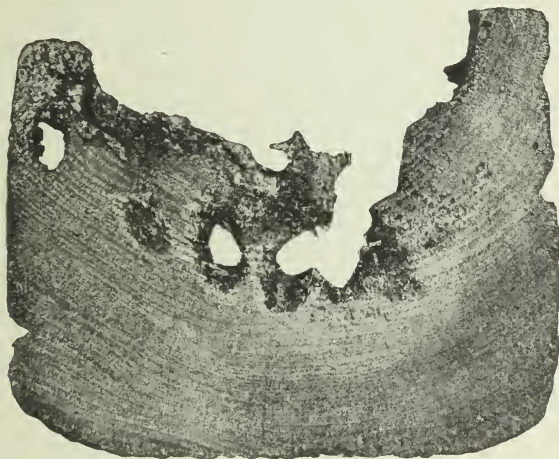


Fig. 1



Fig. 2

Plate I. Cross-sections of posts showing the tendency to rot at the heart first. Fig. 1 is catalpa. Fig. 2 is white cedar.



Plate II. Longitudinal section of a locust post showing tendency to rot at heart first. See pages 613, 614, 622, 625.

The data in detail of one more fence are given below on account of some individual items and for reference later.

TABLE III

OHIO AGRICULTURAL EXPERIMENT STATION

DATA CONCERNING FENCE POSTS

November, 1907.

Dwner John Hyde P. O. Yellow Springs, Ohio.
 County Greene Township Miami
 Location One mile S. of town on W. side of woods, on Xenia pike.
 Kind of Fence Picket
 Direction N-S.
 Soil Clay-loam, limestone.
 Drainage Good.
 Kind of Posts White oak.
 Age 13½ years; set in spring of 1894.
 Time of Cutting Winter.
 Seasoning Green.
 Size of Posts 5 to 7 inch face
 Distance Apart 10 feet.
 Number Sound 152 3 s 87 4 s 29
 Number Rotten 100 3 r 52 4 r 33
 Total Number 252 139 62
 Remarks: 60% s 63% s 47% s

TABLE IV

OHIO AGRICULTURAL EXPERIMENT STATION

POST TO POST RECORD

(u)—set top up. (d)—set top down. (s)—sound. (f)—fair. (p)—poor, (r)—rotten.
 (h)—heart post. (b)—post next to bark. In summary, (f) is classed
 with (s) and (p) with (r).

Owner John Hyde

Beginning at N. W. cor. of woods, go south.

1	1us	3 f	4dr	>1us	3df	3uf	3 s	3 r	4dr
2	2us	2ds	3us	1 s	3 s	4ds	3us	3uf	3 r
3	3 f	4ur	3df	3 r	3 s	4ds	3 f	3 r	4uf
4	2 r	4dr	3us	3 r	3 p	3 s	3 s	3ur	3 s
5	2up	3 f	3 f	3 s	2dr	4us	3us	3 s	3 p
6	2df	2us	3 s	4ur	4ur	4ds	4dr	3 r	3 p
7	2ds	2 f	4us	3ds	3 f	4ds	4dr	3dp	4dp
8	2df	2 s	4us	4ur	4ur	3 p	3dr	3 s	3 r
9	2ur	2uf	4 r	4ur	3 s	4ds	4ur	3 r	3 f
10	2ur	2 s	4ur	4ur	3 f	4us	3 s	3dp	4 s
11	2ds	3 s	4us	3 f	4ur	4us	3us	3 s	3 p
12	2ur	2 s	< 4df	3dr	4ur	4dr	3 r	3 s	3dr
13	2up	3 p	3 s	3uf	3 s	tree	3 r	3 r	3 s
14	2dr	3 r	4dr	2 s	2ds	3us	3 r	3 r	3 p
15	2us	3 s	4dr	3 s	3p	< 4 s	3 r	3 r	3 f
16	4us	3uf	4ur	3us	4ur	4ds	3 r	3 s	3 f
17	2ur	3 f	tree	3us	sas.r	2us	3ur	3 r	4ds
18	3ur	3 f	3 p	3 s	2df	4uf	3 s	3ur	1ds
19	3ur	4dr	3 s	3 s	2ds	4ds	3 s	3 r	
20	2ds	4ur	3uf	3 s	2 s	3ds	3 s	3 r	
21	2uf	2ur	4us	2 r	2 s	3dp	< 3 s	3ur	
22	2ds	2dr	3 s	4ds	2ds	4ds	3us	4dr	
23	2uf	2 p	3ds	3 r	sas.r	3 s	3 s	4ur	
24	2us	3 r	3df	3 r	sas.f	3us	3 f	4ur	
25	2ur	3 s	3 s	3 s	sas.r	3 r	3us	3 r	
26	3 r	4up	3dr	3 f	2ds	3 f	3 s	4dr	
27	2ds	4ds	3 f	3df	3us	tree	3uf	3 s	
28	2 s	4ur	3us	3 s	4us	3 s	3uf	4us	
29	3ur	4 s	4dr	3 s	4dr	3 s	3 f	4us	
30	2us	3 r	3 r	3 s	3us	3dp	2ds	4df	

>—a gate. <—a culvert.

Tables III and IV are the opposite sides of the same leaf of a blank book in which these data are taken. There are two pages of this kind for every fence that has been examined.

In Table IV, the shape of each post is described in order by the figure standing before each set of letters. The figure 1 stands for a round post, see Fig. 1 in accompanying cut; 2 for a wedge shaped post extending from the bark to the center of the tree, see Fig. 2; 3 for one that has had the heart split off, see Fig. 3; 4 a heart post

with three corners, see Fig. 4. For example, post number 15 is a wedge shaped post that extended from the bark to the center of the tree, it was set "top up" and is sound. Number 61 is a three-cornered heart post, set "top down" and is rotten. Number 62 is a post next to the bark but with the heart split off, is set "top up" and is sound.

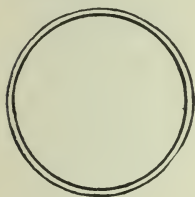


Fig. 1

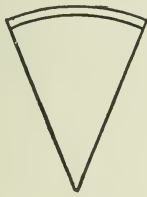


Fig. 2

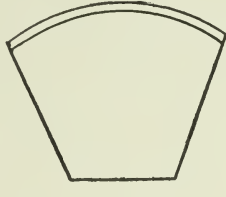


Fig. 3



Fig. 4

It will be noticed here that 63 percent of the posts next to the bark are sound, while only 47 percent of the three-cornered, heart posts are sound.

This characteristic of rotting at the heart first has been observed to a marked extent in the locust, the oak, the hardy catalpa, the white cedar, and to some extent in the red cedar.

In the Wabash Valley, two of the most common shapes of catalpa posts are quarters and halves split from small trees; and those where decay has set in are very frequently found in the shape of a quarter-circle or a half-circle next to the sap wood or bark. The white cedar post, so common along the railroads, is frequently found in the shape of a half-circle a few inches below the top of the ground. See Plates I and II.

This fact may come as a surprise to many; indeed, some have already expressed their surprise at it and still others have refused to believe it. But when we come to look for the cause, it is not quite natural and what might be expected? Let us take for example an oak tree: the oak posts in the fence recorded in Tables III and IV have from five to seven inches face along the medullary rays. This indicates that the trees from which they were split were from 20 to 30 inches in diameter. White oak trees this size are from 150 to 200 years old. Now the only part of a tree that is alive is the part next to the bark. That part of the tree, therefore, from which these three-cornered posts were split, had been dead a hundred years or more when the tree was cut. Then, too, the center of the tree contains numerous little knots, where branches dropped off in the early life of the tree. Some of the branches in falling leave perfectly sound knots, but others offer opportunities for germs and mild decay to set in. This decay may not make any visible progress before the sap wood closes over the defect left by the falling branch.

but its effects will be there, and though it may not cause a rotten place by the time the tree is cut, it may cause the wood for some distance above and below to be a little too dark; that is, instead of bright, reddish straw-color, it will be nearer a maroon or even almost brown. Such wood may be firm and strong, and posts split from it may pass for sound ones, when as a matter of fact this hidden decay has already set in. This quality of post is by no means rare in the fences examined for the preparation of this bulletin. On the other hand, the posts split from the outside of the tree have not been standing in the tree so long, have been formed after the tree was a foot or more in diameter and had a smooth trunk, and the wood therefore is clear of knots and not subject to infections by being exposed to the air through knot holes.

It must not be understood that the white sap wood is referred to here as being durable. In estimating the size of a post split from the outside of the tree, as much post only should be counted as there is heart wood. The wood of good quality referred to here is the heart wood that lies just beneath the sap wood, as compared with the heart wood at the center of the tree.

This same tendency to rot at the heart first is seen in hollow trees and trees dotted at the heart in our native woodlands.

On the following pages are given summaries of the 292 fences examined. These are grouped according to the kind of timber from which the posts were made, and six other items are given, viz.: size of posts, age or time of service, the number sound, the number rotten, the total number, and the percent of sound posts. These seven items are obtainable for the most part from every fence examined and are items vital to all. There are other items in the data recorded that are of supreme importance for certain fences, but are not common to all the fences alike. These will be discussed in the comments on the pages following the tables.

The first column of figures is simply the order of the fences of each kind of timber. The second column designates the order of the fences in the six books in which the data were recorded. The name and address of the owner of any of the fences can be obtained from those six books.

OSAGE ORANGE

		Size	Age	No. Sound	No. Rotten	Total	Percent Sound
	Book No. 1	Inches					
1.....	11	2-3	15	100	0	100	100
2.....	14	3-5	16	109	0	109	100
3.....	19	3-5	21	74	0	74	100
4.....	21	3-5	28	53	1	54	98
5.....	51	2½-4	26	2½	3	31	90½
	Book No. 3						
6.....	16	2-4	15	50	0	50	100
7.....	26	3-5	22-12	79	0	79	100
	Book No. 4						
8.....	14	3-4	15	54	0	54	100
	Book No. 5						
9.....	1	3-5	48	104	0	104	100
10.....	2	2-5	33	494	2	496	99½
11.....	3	2-5	34	531	9	540	98+
12.....	4	5	30-35	68	2	70	97
	Book No. 5						
13.....	5	5-6	30	44	1	45	98
14.....	6	3-6	29½	29	0	29	100
15.....	7	2-4	28½	310	2	312	99
16.....	8	3-4	50	24	0	24	100
17.....	9	3-5	30+	126	4	130	97
18.....	10	4-6	40	90	0	90	100
19.....	11	3-4	36	38	1	39	97
20.....	12	6-12	58	11	0	11	100
21.....	12	6-12	48	28	0	28	100
22.....	13	1-3	40	214	7	221	97
23.....	14	3-5	34	29	1	30	97
24.....	15	6-10	49	18	0	18	100
25.....	16	4×4	33	17	0	17	100
26.....	17	3-5	38	68	4	72	94
27.....	18	3-5	33	92	2	94	98
28.....	19	3-5	40+	49	0	49	100
29.....	20	3-5	28+	61	4	65	94
30.....	21	6×6	12	332	0	332	100
31.....	28	3-5	21	43	0	43	100
32.....	29	3-4	7	130	0	130	100
33.....	30	2½-3	7	40	0	40	100
	Book No. 6						
34.....	32	2½-4	25	27	0	27	100
35.....	33	3-5	47	41	0	41	100
36.....	34	2½-4	25+	41	0	41	100
37.....	35	2-4	30	42	0	42	100
38.....	36	3-4	10+	53	0	53	100
39.....	37	2½-4	17	70	0	70	100
40.....	38	3-4	22	31	0	31	100
41.....	39	3-5	30	67	0	67	100

LOCUST

		Size	Age	No. Sound	No. Rotten	Total	Percent Sound
	Book No. 1						
1.....	12	Medium	14	23	1	24	96
2.....	23	"	31	22	3	25	88
3.....	24	Small	5	26	0	26	100
4.....	25	"	6½	36	8	44	82
5.....	26	Medium	31	45	6	51	88
6.....	30	"	24	67	0	67	100
7.....	31	"	32	115	51	166	69
8.....	45	"	20	126	30	156	81
9.....	46	"	21	143	13	156	91½
10.....	47	"	20	43	8	51	84
11.....	48	"	11	13	1	14	93
	Book No. 3						
12.....	3	Medium	20	111	21	132	84
13.....	7	Large	60?	20	0	20	100
14.....	8	Medium	60?	12	1	13	92
15.....	9	Large	14	63	5	68	93
16.....	15	Medium	8	59	0	59	100
17.....	19	"	30	55	6	61	90
18.....	20	Large	22	54	3	57	95
19.....	39	Medium	22	88	34	122	72
20.....	43	"	40	20	4	24	83
21.....	48	"	8	37	4	41	90
	Book No. 5	Inches					
22.....	27	4-6	42	27	8	35	77
23.....	27	4-6	25	25	1	26	96
24.....	31	3-5	9	32	12	44	73
25.....	32	3½-6	16	1173	98	1271	92
26.....	33	4-5	15?	147	2	149	98½
27.....	34	4-6	16	568	57	625	91
28.....	35	4-6	15	174	6	180	96⅓
29.....	36	5	17	64	0	64	100
	Book No. 6						
30.....	6	4-6	½	13	0	13	100
31.....	12	4-6	6	56	0	56	100
32.....	41	5-9	42	157	17	174	90
33.....	42	6-8	18	87	7	94	92½
34.....	43	4-6	22	35	0	35	100
35.....	44	4-6	22	68	0	68	100
36.....	45	4-5	29	74	49	123	60
37.....	46	6-7	35	62	25	87	71
38.....	51	4-7	17	570	70	640	89

RED CEDAR

	Book No. 1	Inches					
1.....	29	4-7	35	24	27	51	47
2.....	48	5-7	11	14	5	19	74
3.....	44	5-8	50	34	19	53	64
	Book No. 4						
4.....	1	2-5	42	81	59	140	58
5.....	5	4x4	16	141	4	145	97
6.....	6	4-6	30	41	8	49	84
7.....	28	5-8	36	37	29	66	56
8.....	29	5-7	20	26	3	29	90
9.....	30	5-6	18	39	6	45	87
10.....	31	5-8	40+	9	8	17	53
11.....	32	5-8	30	48	13	61	79
12.....	33	5-8	50	4	9	13	31
13.....	34	5-7	18	71	22	93	76+
14.....	35	4-6	45?	20	30	50	40
15.....	36	5-8	40	57	19	76	75
16.....	37	5-8	40	102	89	191	53
17.....	39	8x11	63	4	4	8	50
18.....	41	5-9	36+	73	96	169	43
19.....	42	7-8	40+	11	38	49	22½
20.....	43	3x6	40	15	3	18	83
21.....	44	4-6	7	37	3	40	92½
22.....	45	5-7	12	68	0	68	100
23.....	46	5-7	14	128	2	130	98½
24.....	47	4-6	10	143	0	143	100
25.....	48	4-7	8	136	0	136	100
26.....	49	6x8½	62	11	2	13	85
	Book No. 5						
27.....	25	5-7	?	65	4	69	94
	Book No. 6						
28.....	9	4x4	30	38	7	45	84
29.....	10	4x4	30	29	16	45	64
30.....	11	4x4	30	35	5	40	87½
31.....	47	5	7	16	0	16	100
32.....	48	5	5	61	0	61	100
33.....	49	3-4	2	25	0	25	100

MULBERRY

		Size	Age	No. Sound	No. Rotten	Total	Percent Sound
	Book No. 1	Inches					
1	20	4-6	19	29	11	40	72½
2	38	4-6	19	40	2	42	95
3	40	5-7	13	11	2	13	85
4	41	4-6	20	57	31	88	65
	Book No. 2						
5	29	4-7	30	22	14	36	61
6	20	4-7	16	4	6	10	40
7	19	4-7	24	9	5	14	64
8	18	4-7	16	31	29	60	51½
9	17	4-6	24	10	7	17	59
10	11	4-6	20	4	2	6	66½
11	3	4-7	15	6	2	8	75
	Book No. 3						
12	4	4-7	37	41	8	49	84
13	26	4-6	22	11	2	13	84½
	Book No. 5						
14	24	4-5	?	24	7	31	77
	Book No. 6						
15	19	4-6	25	95	5	100	95

WHITE CEDAR

1	Book No. 1	4-6	19	31	9	40	77½
	Book No. 3						
2	21	4-7	17	122	44	166	73½
3	22	4-7	17	174	72	246	71
4	23	5-7	17	51	15	66	77
5	24	5-7	18	31	39	70	44½
6	25	5-7	20?	59	47	106	56
	Book No. 6						
7	14	5-7	15	84	7	91	92
8	23	4-5	25	33	26	59	56
9	24	4-5	25	53	17	70	76
10	25	6-9	8	738	12	750	98½
11	25	6-9	8	712	38	750	95
12	26	6-9	8	195	15	210	93
13	26	6-9	8	178	32	210	85
14	28	5-7	11	83	16	99	84

CATALPA

1	Book No. 1	6-9	25	14	7	21	66½
2	3	5x5	11	0	11	11	0
3	4	4x5	12	4	11	15	27
4	5	6-9	17	55	34	89	62
5	6	5-7	18				40
6	7	6-9	34	9	2	11	82
7	9	4-6	20	30	30	60	50
8	10	5-6	31	23	3	26	88½
9	12	5-6	14	16	8	24	66½
10	13	6-9	14	43	34	77	56
11	16	5-6	27	8	10	18	44½
	Book No. 2						
12	42	5-6	5½	3	9	12	25
13	39	5-6	15	256	40	296	86½
14	38	5-6	21	47	31	78	60
15	37	5-6	20	30	13	43	70
16	36	4-6	14?	97	10	107	91
17	35	5-6	16	30	17	47	64
18	35	5-6	15	6	5	11	54½
19	34	5-6	13	29	13	42	69
20	33	5-6	17	55	25	80	69
21	32	5-6	17	22	15	37	59
22	31	5-6	25	57	28	85	67
23	30	5-6	18	28	31	59	47½
24	29	5-7	30	19	17	36	53
25	28	5-6	13	17	23	40	42½
26	27	5-6	22	26	29	55	47
27	26	5-6	13	37	49	86	43
28	25	5-6	16	2	21	23	9
29	24	5-6	7	151	16	167	90½
30	23	5-8	25	9	32	41	22
31	22	5-6	16	21	25	46	46
32	21	5-6	16	38	27	65	58½
33	20	5-6	16	39	7	46	85

CATALPA—Concluded

		Size	Age	No. Sound	No. Rotten	Total	Percent Sound
	Book No. 2	Inches					
34	19	6-9	24	25	23	48	52
35	17	5-6	24	11	17	28	39
36	16	5-6	13	19	12	31	61
37	15	4-6	27	10	14	24	41½
38	14	6-9	18	47	42	89	53
39	12	6-8	21	34	17	51	67
40	13	5-6	15	53	3	56	95
41	11	6-8	20	56	17	73	77
42	19	6-8	23	59	58	117	50½
43	9	5-8	14	103	24	127	81
44	8	5-6	16	67	12	79	85
45	7	4-5	30	27	185	212	13
46	4	5-6	15	69	54	123	56
47	3	5-6	15	126	77	203	62
48	2	5-6	19	104	42	146	71
49	2	5-6	17	92	15	107	86
50	1	5-6	18	96	56	152	63
51	48	5-6	1	36	0	36	100
52	40	5-8	39	12	53	65	18½
	Book No. 4						
53	1	3½-6	7	93	7	100	93
54	2	3½-6	7	126	4	130	97
55	3	3-5	7	463	45	508	91
56	4	3-5	7	470	70	540	87
57	5	3-5	6½	220	21	241	91
58	6	3-5	6½	175	9	184	95
59	7	3-4½	2	100	0	100	100
60	8	3-5	6½	103	8	111	93
61	9	4	3	100	0	100	100
62	10	4	3	173	2	175	99
63	11	4-5	3	104	0	104	100
64	12	4-5	3	212	3	215	99
65	13	4-6	6	604	22	626	96½
66	14	3-4	3	136	2	138	98½
67	15	4-5	4	138	0	138	100
68	16	3-4	16	46	12	58	79
69	17	2½-4	20	11	26	37	30
70	18	2½-4	14	91	22	113	81
71	19	4	5	181	110	191	95
72	20	2-3	6½	270	150	420	64
73	21	2-3	4½	362	18	480	75
74	22	2½-3½	5½	208	28	236	88
75	23	2½-3½	5½	186	15	201	92½
76	24	2½-3½	5½	73	7	80	91
77	25	2½-4	9	592	188	780	76
78	26	2½	5½	39	13	52	75
79	27	4-5	3½	538	2	540	99½
80	28	2½-3	8	119	25	144	83
81	29	3-4	6	68	10	78	87
82	30	3½-5	6	830	20	850	98
83	31	4-5	6	684	24	708	96½
84	32	4-5	¼	60	0	60	100
	Book No. 6						
85	1	5-6	4	85	0	85	100
86	2	3-5	11	30	0	30	100
87	3	4-6	8+	12	4	16	75
88	4	5-7	6	28	4	32	87½
89	5	5-7	11	33	0	33	100
90	6	4-6	½	73	0	73	100
91	7	4-5	6	34	0	34	100
92	12	4-6	6	25	0	25	100
93	13	3-4	11	13	3	16	81
94	50	5-7	11	8	10	18	45
95	50	5-7	11	27	16	43	63

CHESTNUT

		Size	Age	No. Sound	No. Rotten	Total	Percent Sound
	Book No. 1	Inches					
1	32	5-6	9	15	3	18	83½
2	39	5-6	11	57	24	81	70½
3	39	5-6	7	37	3	40	92½
4	44	5-6	9	116	49	165	70½
5	53	5-6	9	38	7	45	84½
6	54	5-6	8	9	5	14	64
	Book No. 3						
7	10	4-6	13	61	17	78	78
8	11	5-6	13	46	14	60	77
9	12	5-7	16	171	102	273	62½
10	13	5-6	13	77	33	110	70
11	14	5-6	13	50	51	101	50
12	18	5-6	28	8	8	16	50
13	27	5-6	11	157	74	231	68
14	50	5-6	13	22	36	58	38
15	51	5-6	12	36	34	70	51½
	Book No. 5						
16	22	5-6	12	42	11	53	79
17	23	5-8	8	63	4	67	94
	Book No. 6						
18	8	3-5	10	43	19	62	69

OAK

	Book No. 1						
1	27	5-6	12	19	2	21	90½
2	28	5-6	9	57	40	97	59
3	32	5-6	9	14	3	17	82
4	33	4-5	17	38	30	68	56
5	34	4-5	16	26	53	79	33
6	35	4-6	14	37	12	49	75½
7	36	4-6	14	49	21	70	70
8	37	4-6	20	21	3	24	87½
9	40	4-6	13	49	18	67	73
10	41	4-6	20	10	21	31	32
11	42	4-6	16	23	27	50	46
12	43	4-6	8	43	13	56	77
13	50	4-6	12	155	95	250	62
14	51	4-5	23	27	3	30	90
	Book No. 2						
15	34	4-6	13	25	37	62	40
16	25	4-6	16	7	13	20	35
17	11	4-6	20	21	27	48	44
18	45	5-7	13	152	100	252	60
19	45	5-7	13	187	105	292	64
	Book No. 3						
20	2	4-6	25	18	18	36	50
21	17	4-6	15	18	0	18	100
22	47	4-6	10	53	22	75	71
23	50	4-5	13	5	8	13	38½
	Book No. 5						
24	26	3-5	18	7	22	29	24
	Book No. 6						
25	20	4-5	25?	43	14	57	75½
26	27	4-5	8	31	15	46	67
27	40	5-6	18	33	3	36	92
28	45	4-5	29	11	13	24	46

HONEY LOCUST

	Book No. 3						
1	17	4-6	15	15	29	44	34
	Book No. 6						
2	15	6-8	4	83	0	83	100
3	16	5-8	4	24	0	24	100

SASSAFRAS

	Book No. 6						
1	17	5-6	4	57	0	57	100

BLACK ASH

	Book No. 6						
1	18	5-6	2	28	0	28	100
2	21	6-8	7	38	20	58	65½
3	22	6-8	6	17	10	27	63
4	29	6-7	8	*	*	*	†
5	30	6-8	9+	*	*	*	†
6	31	5-7	4½	14	2	16	87½

*Several hundred.

†Very few.

COMMENTS ON A FEW OF THE ABOVE FENCES THAT HAVE SOME POINT OF SPECIAL INTEREST

OSAGE ORANGE, No. 5. These posts were made from a hedge that had been kept cut back about 4 feet high for a number of years. It was allowed to grow ten or fifteen years and was then cut down at the ground and the larger ones were made into posts.

Several of these posts had defective places about 4 feet from the big end, caused by cutting the hedge back year after year at this point. The posts were set with the small end down. This put the defective place just beneath the top of the ground. The three poor or rotten posts failed at this point.

OSAGE ORANGE, Nos. 9 TO 30. These fences are in Texas. The majority of the posts are split, some are round, a few are sawed and hewed.

Nos. 20 and 21 are blocks used for the foundation of a house. These are from 6 to 12 inches in diameter. No. 24 is a lot of long posts used to support a shed around three sides of a barn. They are 6 to 10 inches in diameter. The rest are posts in ordinary fences. They range in size from 2 to 6 inches in diameter, the majority of them between 3 and 4 inches in diameter.

OSAGE ORANGE No. 29. This fence was built before barbed wire came into general use. Small holes are bored about nine inches apart along one edge of the posts. Smooth wire was fastened in these holes in such a way as to make loops (see Plate VIII). Rails split from the Osage orange tree are inserted into these loops. This makes a fence in which there is nothing but Osage orange wood and No. 9 wire. The present owner bought the farm 28 years ago. He was acquainted with it some 12 or 15 years before he bought it. The posts were in service and looked very old the first time he ever saw them.

The writer, while in conversation with the owner of fence No. 19, asked him if there was a good market for posts in that vicinity. He said they were not as ready sale as they used to be. When asked for the cause of this he replied: "Well the country was all fenced 30 to 50 years ago and we do not need any more posts."

Any one who drives about over that part of the country must conclude that this was not far from the truth, for the posts in most of the fences are rather ancient looking, frequently being in a large measure covered with moss and lichens.

This timber is certainly one of extremes. Besides its remarkable durability in the soil, it is just as remarkable in its standing qualities when seasoned and in its elasticity.

The man just referred to above has a wagon made of Osage orange. He bought this wagon second hand, 40 years ago. Neither wheel has ever had a tire shrunk and the tires are as tight today as they were the day they were put on. The wheels, when struck a sharp blow, ring as if they were one solid piece of metal.

The wood seems to have been named from its elastic properties. The name is composed of three French words: "*bois*", wood; "*de*", "of" or "for"; and "*arc*", a bow, thus *bois d'arc* means wood for the bow. In this bulletin the term "Osage orange" is used because that name seems to be more widely understood in this state, although "*bois d'arc*" is the name almost universally used in the south-west, where the tree is native.

A well digger at Yellow Springs, Ohio has a drill that weighs about 500 pounds. His machine is constructed in such a way that, when the drill falls, the cable that supports it is stretched just as the drill strikes. This cable is

fastened to the end of a pole which must be elastic and must sustain a weight of 100 to 500 pounds. The toughest white oak or hickory in this position lasts about three months. The Osage orange pole that he has there at present has been there three years and shows no sign of weakening.



Fig. 1



Fig. 2

Plate III. Fig. 1, Cross-section of a locust post that was sound after 31 years of service in the soil. Note how close the annual rings are. Fig. 2, Cross-section of a locust post that had rotted off in five years. Note how large the annual rings are. See page 622.

LOCUST No. 1. This is a line fence between two farmers. One man furnished locust posts, the other hardy catalpa. The posts were set alternate. Of the 24 locusts, 23 are sound; of the 24 catalpas, 16 are sound. Both kinds were seasoned when set. The posts of each kind were of fair quality except post No. 20 of the locusts. It was small and worm eaten.

LOCUST Nos. 4 AND 5. Thirty-one years ago (from the time these two fences were examined) the owner went to a locust grove, cut posts and built fence No. 5. Six years ago his son went to the same grove, cut posts and built fence No. 4. The 31-year-old fence has 88 percent sound posts, the 6-year-old has only 82 percent sound. In the 6-year-old fence, the most of the posts show very rapid growth, especially near the heart; the annual rings are from one-fourth to three-fourths of an inch thick. Many of the posts had a dark brown color, rather than a bright straw color, and a few were even dotted at the heart when set. Further investigation showed that these posts were made from trees that had grown from stumps from which the posts for the older fence had been cut 25 years before. (see Plate III).

The 6-year-old fence was examined again about two and a half years later, that is when it was nearly nine years old, and was found at that age to be only 73 percent sound. It is recorded in locust fence No. 24.

LOCUST Nos. 8, 9 AND 10. These three fences furnish some very interesting data. First, it will be noticed that No. 9, which is one year older, has 91½ percent sound posts, while the other two have only 84½ percent and 81 percent sound. All three fences are made from the same lot of posts. Selection alone is the cause of this difference. The first 75 posts in fence No. 9 are along a line between two farms, and the man who built the fence selected the larger and more perfect posts for this line. Of these 75, 72 are sound, or 96 percent.

These three fences all agree in their testimony that three-cornered heart posts show more decay than the flat ones that were split out next to the sap wood. They also show a greater percent of sound posts among those that are set with the top up than those set with the top down. The cause for this would seem to be that the post at the top end is a little smaller and therefore does not last quite as long. In oak posts split from large trees, where the taper of the post is not so evident, this difference in durability is not so noticeable.

LOCUST No. 13. This fence is interesting as a curio rather than for scientific data of any value. The posts are made from railway cross-ties that are said to have been put in when the Little Miami Railroad was built. They remained in the road-bed until the track was reconstructed and larger rails were put on. The ties were at that time discarded because they were so hard that the men could not drive the new spikes into them nor pull the old ones out. They were brought up to Xenia by the section foreman and put into the present position. These posts serve to show that some posts or ties of locust will endure for a remarkably long time; but they are not worth much as data upon which to estimate the durability of timber, because it is not known how many had rotted by the side of these in the track.

LOCUST No. 20. This is a garden fence in which are locust and red cedar, both of first quality, and the two kinds show the same percent of sound posts. The cedar posts are recorded in red cedar fence No. 20.

RED CEDAR No. 2. Compare this fence with red cedar No. 26. No. 2 has 74 percent sound in 11 years. No. 26 has 85 percent sound in 62 years. The posts in No. 26 are slightly larger, although those in No. 2 are good sized posts, having from 4 to 6 inches of red wood.

The wood in each case was pure, healthy growth, no indication of doted wood when posts were set. When two fences of the same kind of wood differ as widely as these when both are made of healthy wood, there is a financial or economic matter involved, that should call forth our closest scrutiny.

The posts in No. 2 grew in the open and have from 4 to 6 annual rings to the inch. Those in No. 26 have from 50 to 60 annual rings to the inch. The rings are so close that the microscope had to be used to count them (see Plates IV and V).



Plate IV. Cross-section of a red cedar post, sound after 62 years in the soil. The cut is the same size as the block from which it was taken. At one corner of this block there are 68 rings to one inch.

RED CEDAR Nos. 13 AND 15. No. 13 is 18 years old and about 76 percent sound. No. 15 is 40 years old and has 75 percent sound.

No. 13 has from 6 to 11 rings to the inch. No. 15 has 30 to 50.

In this case the two fences are on the same farm and begin within a hundred yards of each other. One is more than twice as old as the other, but the percent of sound posts is almost the same. Red cedar that grows in the open has wide annual rings, is apt to have large and numerous knots, a very thick sap wood, the red is not as deep color, and usually has more of those pale red or almost white spots that are commonly mixed in with the heart wood of this tree. This quality of post has been observed, a few at a place, at numerous places over the state, and they regularly show poor record. The red cedar fences, however, where there is a considerable number of posts in one string, are usually made of those that have been shipped from where they grew in the timber.

The above characteristic has been watched quite closely throughout and it is observed to be quite a regular law that the closer the rings the better the quality for posts.

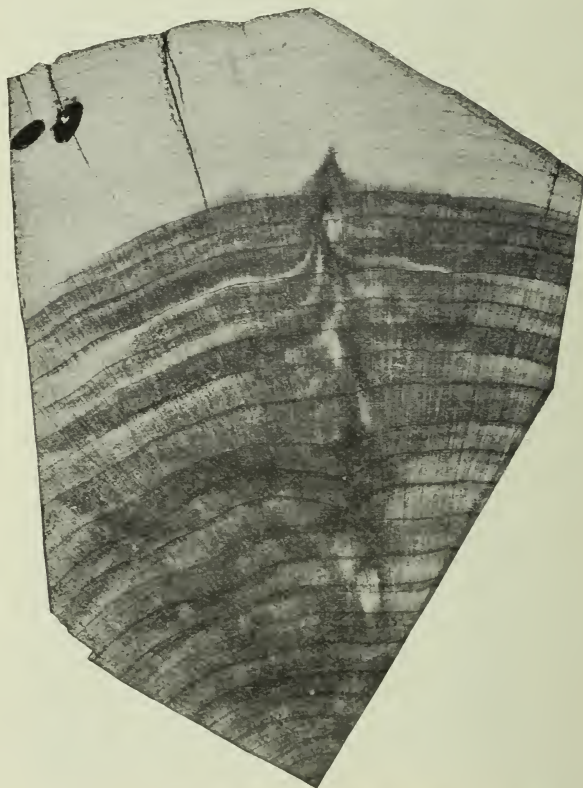


Plate V. Cross-section of a red cedar post that was rotten in 9 years. Cut was reduced one-third in diameter from the block of wood. The rings on the wood are just 4 to the inch. See pages 622-624.

RED CEDAR No. 20. These posts are set alternately with locust and have the same percent sound as the locust. Described under locust fence No. 20.

RED CEDAR No. 21. Fence is only 7 years old but is showing considerable decay, $7\frac{1}{2}$ percent. Posts grew in an old field but in some places with rather thick stand. Rings are from 9 to 12 to the inch. Posts were cut in April.

RED CEDAR No. 22. Came from same grove as those in No. 21 but from denser portion. Most of these have about 20 rings per inch. The posts also average larger. Posts were cut in January. They are all sound at 12 years, while those of fence No. 21 have $7\frac{1}{2}$ percent rotten in 7 years.

MULBERRY No. 1. These posts are set alternately with native-grown white cedar, 40 posts of each kind. Mulberries $72\frac{1}{2}$ percent sound, cedar $77\frac{1}{2}$ percent sound. The mulberries are of only moderately good quality. Compare white cedar No. 1.

MULBERRY No. 2. Posts here are of very fine quality. Note the difference between this and fence No. 1. No. 1, 19 years old, 73 percent sound, No. 2, same age, 95 percent sound. These posts were clear, bright yellow, while those in fence No. 1 frequently were too dark in color and had more little defective places. Some of them seem to have been split from trees on the decline. So much for good quality.

MULBERRY No. 3. Are set with white oak. Mulberry 85 percent sound, oak 73 percent. Mulberry posts were made from dead trees, quality not very good; cf. oak fence No. 9.

MULBERRY No. 4. A yard fence with 88 mulberry posts and 31 oak, each of good quality of its kind, each kind seasoned about one year. Mulberry 65 percent, oak 32 percent sound. This fence is a very important one, because the two kinds have had the same treatment and each is a good specimen of its kind.

MULBERRY No. 5. Fence is a mixture of mulberry and catalpa, in which the mulberry seems to be the better, each a good quality of its kind. Mulberry 61 percent, catalpa 53 percent sound; cf. catalpa fence No. 24.

MULBERRY No. 6. A mixture of mulberry and catalpa in which the catalpa has the advantage. The mulberry is not a good quality of its kind. Mulberry 40 percent, catalpa 85 percent sound; cf. catalpa No. 33.

MULBERRY Nos. 7 AND 9. Mixed with catalpa, in which mulberry shows the better record. The mulberries 64 percent and 59 percent sound, catalpas 52 percent and 39 percent sound,

WHITE CEDAR No. 1. Fence contains 40 white cedar and 40 mulberry. Cedar, $77\frac{1}{2}$ percent sound; mulberry, $72\frac{1}{2}$ percent sound. See mulberry fence No. 1.

WHITE CEDAR Nos. 2, 3 AND 4. A large number of these posts are halves sawed from small sized trees. Those marked "p" and "f" usually show that decay began at the heart. Quite frequently, all that is left of the post where it enters the ground is a half-circle next to the sap wood. See Plates I and II.

A considerable portion of these posts had what is known as "pipe rot" when set. "Pipe rot" is a term applied to white cedar that has a little dotted place or a little hollow about an inch in diameter extending through the length of the post. This is very frequent with the white cedar and dealers in selling sometimes specify that "pipe rot" shall not be considered a defect such as to bar the post thus affected from the first class.

WHITE CEDAR No. 6. All the rotten posts in this fence were removed in the summer of 1907, and locust put in their places. The locusts were taken from the east line of the farm, from a fence that was built in 1874, along a lane. The lane was abandoned in 1907 and the locust fence was moved out onto the line, and wire was put on instead of the old boards. Thus fewer posts were used. The posts that were brought over to the white cedar fence were set with the same end in the ground as in the former fence. The condition of the locust fence may be seen in locust No. 7, which was 32 years old and had 69 percent sound.

CATALPA No. 2. The posts in this fence were hewn from small trees that were mere bushes when the other timber was cut off. They were left and grew thus in the open, in rich, bottom land. They were all pure heart wood with no decayed places. The owner thought when he finished this fence that he would never have to build another in the same place. But it all went down in eleven years.

There were short posts set alternately with the regular posts. These just came to the top of the base-board of the fence. These short posts were cut from slow growth catalpas in the woods; some of them were pieces of old posts. A good percentage of the short ones were sound when the fence was removed. See Plate VI.

CATALPA No. 5. Age 18 years. The north end of this fence originally contained catalpa, mulberry, burr oak, honey locust, and sassafras. The honey locust and the sassafras are all gone. Of the other three kinds, the owner says he has taken out more oaks than any other. The south half of the fence has never had any posts removed. They are mostly catalpa and mulberry. The mulberry is in a little better condition than the catalpa.

CATALPA No. 9. Age 14 years, 66 percent sound. These are alternate with locust in fence No. 1 under locust, and are discussed there.

CATALPA No. 12. Age $5\frac{1}{2}$ years, 25 percent sound. These were cut from trees that grew in low rich land, just inside of a field, along a road. The growth was very rapid, the annual rings frequently being three fourths of an inch thick. The posts were cut just as the buds began to swell, and set green.

CATALPA No. 13. Age 15 years, $86\frac{1}{2}$ percent sound. These posts stood 15 years, then were turned over and the other end was put in the ground. The exact condition therefore for these first 15 years can be seen by looking at the top of the present posts. Very few posts were discarded in resetting. If a post had rotted off in the 15 years, a piece was nailed on the top of it when reset. Posts are of fine quality, with close grain.

CATALPA No. 14. Age 21 years, 60 percent sound. Is a continuation of fence No. 13, but this part has never been reset nor mended. It stood six years longer, or 21 years and shows 60 percent sound as compared with $82\frac{1}{2}$ percent sound in the 15 year-old fence.

CATALPA No. 19. Age 13 years, fence contains 42 catalpa and 62 oak posts, catalpa 69 percent and oak 40 percent sound. Each kind only medium in quality.

CATALPA No. 22. Age 25 years, 67 percent sound, is a fine quality of catalpa grown in dense timber. No posts have ever been removed from fence. Some of these posts sent out sprouts as they stood in the fence. One of these was left and is now a tree about 40 feet tall. Posts were cut in the winter and set green. Compare catalpa fence No. 12.

CATALPA No. 25. Age 13 years, 43 percent sound. Posts were cut April. They show poor record, only 43 percent sound in 13 years though they were a good quality of timber, close grain. Compare catalpa No. 12.

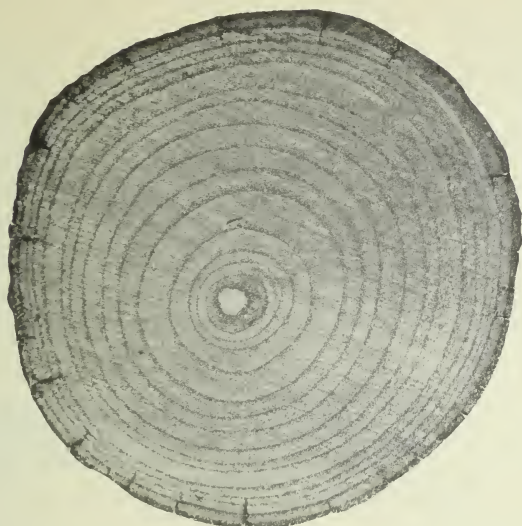


Fig. 1

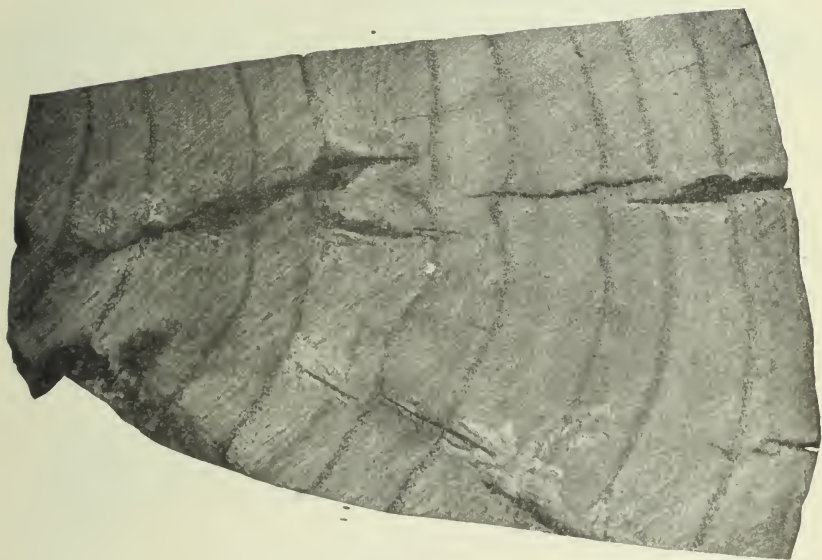


Fig. 2

Plate VI. Fig. 1, Cross-section of a catalpa post, sound after 15 years in the soil. Note how close the annual rings are. See page 626. Fig. 2. Cross-section of a catalpa post rotten in 6 years. Note the large annual rings.

CATALPA Nos. 27 AND 28. Age 13 years, 43 percent sound, and age 16 years, 9 percent sound. Many of the posts in these two fences have annual rings on the outside about twice as thick as the average thickness for trees grown in dense timber. These posts were made from trees that grew in their early life among other trees which were afterwards cut away, leaving the

catalpa in an open woods. That part of these posts, therefore, which in other posts is best, that is, the part next to the sap wood, shows rapid growth. This may be the cause of the poor record in these two fences. Some oak posts in No. 28 are 35 percent sound, while catalpa in same fence are only 9 percent sound.

CATALPA No. 35. Fence contains mulberry posts also, that show 59 percent sound, while the catalpas show 39 percent sound. Has never been reset. Each is good quality of its kind; cf. mulberry No. 9. Both kinds were seasoned.

CATALPA No. 38. Is the same fence as catalpa No. 4, but one year later, showing 53 percent sound as against 62 percent sound one year before. Seasoned.

CATALPA No. 41. In same fence are 48 posts of fine quality of white oak. No posts have ever been removed. The catalpa shows 77 percent sound, the oak 44 percent; cf. oak fence No. 17. Age 20 years, well seasoned.

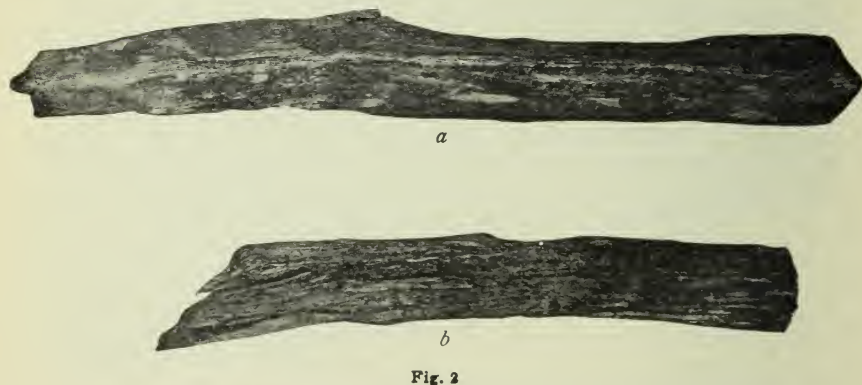
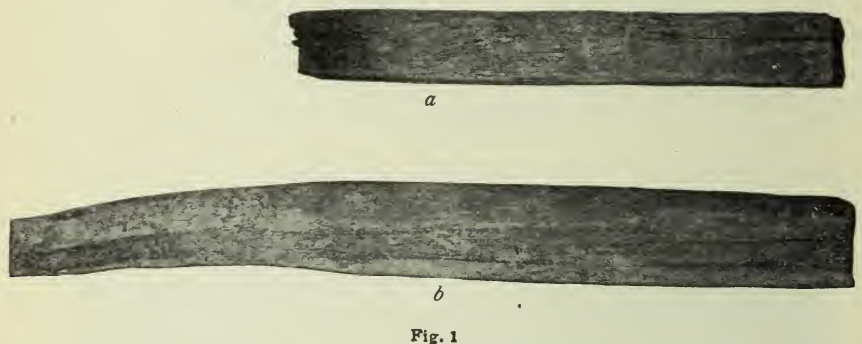


Plate VII. Fig. 1, (a) Catalpa post from a fence eleven years old and all rotten. Posts in this fence are from trees of rapid growth. (b) Catalpa post from a fence 25 years old. Two-thirds of the posts are sound. Trees from which the posts were made, grew very slow in dense forest.

Fig. 2, (a) Locust post from fence 6 years old, rapid growth. (b) Locust post from a fence 31 years old, slow growth. The two fences have the same percentage of rotten posts. See page 639.

CATALPA Nos. 53-84. All the catalpa posts in fences 53-84, 8514 in number, were grown in cultivated groves. They are all round and small, from $2\frac{1}{2}$ to 5 inches in diameter at the ground. The great mass of them are between 3 and 4 inches in diameter. They were grown in Kansas, with a few exceptions in the Farlington, the Hunnewell, and the Munger plantations. The posts at the top end have from 13 to 20 annual rings, usually about 15 or 16. These rings are much wider near the center than near the bark. The first 3 rings are frequently about $\frac{1}{2}$, $\frac{1}{3}$ and $\frac{1}{4}$ inch thick; whereas on the outside it takes 8 to 10 to make an inch. See Plate VI, Fig. 1.

The trees from which these posts were cut were planted 4 x 4 feet, and after the first few years there was of course intense crowding. This caused the outer layers, the outside half of the post, to have about the same rate of growth and same texture as that grown in native woodlands in the Wabash valley. Since the posts are all round, that part of the post that grew slowly is next to the soil.

The sap wood of the catalpa is confined to the two outside rings. This holds good for the thrifty and the crowded tree alike. The thickness, therefore, of the sap wood in these posts is a mere trifle, frequently not more than the tenth of an inch; and although the post may seem quite small, still it has a comparatively good amount of serviceable heart timber.

There is a good lesson for the tree grower in this; that is, when a grove begins to get crowded and the trees are growing more slowly, they are probably putting on a better quality of post material, and besides, the increase of serviceable post timber is more than the current year's growth would indicate.

Let us suppose that on a given tree the annual rings for the years 1906, 1907, 1908, 1909, are 1-6, 1-7, 1-8, 1-9 of an inch in thickness.

These rings represent the amount of growth of the tree in the respective years, but the layer 1-6 of an inch thick was changed to heart wood in the year 1908 and the layer 1-7 of an inch thick will be changed to heart wood or serviceable wood in 1909. The increase of serviceable wood therefore for the years 1908 and 1909 is the amount that grew in the years 1906 and 1907.

So far, therefore, as these two points are concerned, it would seem advisable to let a grove stand a few years after it has become crowded.

CATALPA No. 72. These are mere stakes, about $2\frac{1}{2}$ inches in diameter, all round. They were cut from little trees 7 years old. They have been in the ground $6\frac{1}{2}$ years and are 64 percent sound.

This should be compared with catalpa fence No. 80, in which the posts are but little larger, $2\frac{1}{2}$ to 3 inches in diameter, but were cut from trees 13 to 14 years old, growth about half as rapid as those in No. 72. Fence No. 80 is 8 years old and has 83 percent sound.

CATALPA Nos. 85-93. The posts in catalpa fences 85-93 were cut from trees that grew in Ohio in cultivated groves.

CATALPA Nos. 86 AND 88. Notice here that fence No. 86 is 11 years old and 100 percent sound and that No. 88 is only 6 years old and only $87\frac{1}{2}$ percent sound.

The posts in No. 86 are very small but they are made from very slow growing trees. Those in No. 88 are from fast growing trees.

CHESTNUT No. 1. These posts are set alternately with white oak of about the same size, Chestnut $83\frac{1}{4}$ percent sound, oak 82 percent sound; cf. oak No. 3.

CHESTNUT No. 14. Fence contains 58 chestnut and 13 oak posts, about same percent of each sound. The oak were of poor quality.

OAK No. 2. Age 9 years, 59 percent sound. Two years after this fence was examined so many of the posts were rotten that the fence had to be reset. The first eight posts at the north end of the fence are good quality of locust, one of which is rotten. These locust posts are now standing with the fourth set of oak.

OAK No. 3. Posts are 82 percent sound, set alternately with chestnut $83\frac{1}{3}$ percent sound.

OAK No. 9. Mixed with mulberry. Oak 73 percent, mulberry 85 percent sound.

OAK No. 10. Is mixed with mulberry No. 4, age 20 years. Oak 32 percent mulberry 65 percent sound.

OAK No. 12. Most of the rotten posts here are three-cornered heart posts.

OAK No. 14. Age 23 years, 90 percent sound. These posts are made from the chinquapin oak, or white barked chestnut oak. Posts were put in the ground the same day they were split. It is a rather remarkable record for oak. They are of very fine quality.

OAK No. 15. Posts are set with catalpa in which catalpas are 69 percent and oaks are 40 percent sound; cf. catalpa fence No. 19.

OAK No. 16. These are set with catalpa that has rather rapid growth on outside of post. Catalpa 9 percent sound, oak 35 percent sound. See catalpa fence No. 28.

OAK No. 17. Catalpa and oak mixed. Catalpa 77 percent, oak 44 percent sound. Good quality of each kind. See catalpa fence No. 41.

OAK No. 18. This fence is given in detail in Tables III and IV. It will be noticed that three-cornered, heart posts here show poor record. These three-cornered ones are quite large in this fence.

There are four round sassafras posts here, Nos. 137, 143, 144 and 145. They are seven or eight inches in diameter, one is sound, three are rotten.

OAK No. 19 Age here is a little uncertain, but these are very fine quality of oak.

OAK No. 22. Fence contains 143 good quality red cedar and 75 oak posts. Cedar all sound, oak 71 percent sound. See red cedar fence No. 24.

OAK No. 23. Set with chestnut. Oak 39 percent; chestnut 38 percent sound. See chestnut fence No. 14.

HONEY LOCUST No. 1. Age 15 years, 34 percent sound. This is the only fence of honey locust of any considerable length and age that has been examined. They have been found, a few at a place, in several other fences, and have shown poor record.

BLACK ASH FENCES. I find a number of men who speak very highly of the black ash for post timber, but the fences and telephone lines in the north-west part of Ohio do not seem to justify this estimate.

In making an estimate of the worth of a given timber, several things should be considered.

It has been pointed out above that posts are frequently set that are in poor condition when set, that is, they may have been grown or cut under unfavorable conditions, or they may be too dark in color, not entirely healthy, or even doted to a considerable extent.

Fences that are made in part or entirely of such posts are not so valuable for data, since there is no means of estimating to what extent they are defective.

They may be used to show the tendency of such timber to be thus affected.

Thus for example locust fence No. 4 should be rejected in making an estimate, because the posts were of very poor quality, some of them even beginning to decay when they were set. In $6\frac{1}{2}$ years 18 percent of these were rotten.

Locust No. 13 contains 20 posts that have been in service for probably 60 years and are all sound. This should not be counted in making estimates, for these were made from old railroad ties and, though these 20 show remarkable record, yet there is no way of knowing how many rotted by the side of them in the track. It would be just as fair to gather up the rotten, if that were possible, and estimate the locust from them.

Catalpa fence No. 12, which at the age of $5\frac{1}{2}$ years had only 25 percent sound posts, is an extreme case. It contains two suspicious elements, very rapid growth and posts were cut just as buds began to swell.

Catalpa fences Nos. 72 and 73 should be rejected, because the posts are so small and grew rather fast, and had but little heart wood. These contain 64 percent and 75 percent sound.

Osage orange Nos. 20 and 21 should be rejected on account of large size, being from 6 to 12 inches in diameter. These are 58 and 48 years old, respectively, and none are rotten.

Red cedar No. 2 contains only 74 percent sound posts in 11 years. It should be taken into consideration where these grew, that is, out in the field.

Red cedar No. 17, 50 percent sound in 63 years, should be rejected on account of size. They are about a foot square.

Fences therefore that are to be used as a basis for conclusions should contain posts made from average timber and should contain a goodly number of posts.

The following tables contain the data on a few characteristic fences. Each fence is a good example of its kind, and none are put in this list except those on which very accurate data could be obtained. They are average fences in which the posts were sound when set. Each group will therefore reflect a comparatively correct estimate of the kind of posts that it contains.

OSAGE ORANGE				
Age of Fence	Number sound posts	Number rotten posts	Total	Percent sound
28.....	53	1	54	98.1
33.....	494	2	496	99.6
29.....	310	2	312	99.3
36.....	38	1	39	97.4
40.....	49	0	40	100
33.....	17	0	17	100
Average Age, 33.2	Average Percent Sound,			99
LOCUST				
31.....	22	3	25	88
32.....	115	51	166	69.3
20.....	126	30	156	80.8
21.....	143	13	156	91.7
22.....	111	21	132	84.1
30.....	55	6	61	90.1
22.....	88	34	122	72.1
Average Age, 25.4	Average Percent Sound,			82.3
RED CEDAR				
35.....	24	27	51	47
42.....	81	59	140	57.9
36.....	37	29	66	56.1
30.....	48	13	61	78.7
18.....	71	22	93	76.3
38.....	57	19	76	75
Average Age, 33.2	Average Percent Sound,			65.2
MULBERRY				
19.....	29	11	40	72.5
20.....	57	31	88	64.8
19.....	20	2	22	90.9
24.....	10	7	17	58.8
37.....	41	8	49	83.7
Average Age, 23.8	Average Percent Sound,			74.1
WHITE CEDAR				
17.....	122	44	166	77.5
17.....	174	72	246	71
15.....	84	7	91	92
25.....	33	26	59	56
18.....	31	39	70	44
Average age, 18.4	Average Percent Sound,			68
CATALPA				
25.....	14	7	21	66.6
17.....	55	34	89	61.8
20.....	30	30	60	50
14.....	43	34	77	55.8
21.....	47	31	78	60.2
25.....	57	28	85	67.1
22.....	26	29	55	47.3
13.....	37	49	86	43
14.....	103	24	127	81.1
15.....	69	54	123	56.1
7.....	463	45	508	91.1
Average Age, 17.5	Average percent Sound,			61.8

Age of Fence	Number sound posts	Number rotten posts	Total	Percent sound
CHESTNUT				
11.....	57	24	81	70.4
9.....	116	49	165	70.3
13.....	61	17	78	78.2
16.....	171	102	273	62.7
12.....	42	11	53	79.2
13.....	77	33	110	70
Average Age, 12.3	Average percent Sound, 71.8			
OAK				
9.....	57	40	97	58.8
17.....	38	30	68	55.9
14.....	49	21	70	70
13.....	145	97	246	58.9
8.....	43	13	56	76.8
10.....	53	22	75	69.7
Average Age, 11.8	Average Percent Sound, 65.2			
BLACK ASH				
7.....	38	20	58	65.5
6.....	17	10	27	62.9
Average Age, 6.5	Average Percent Sound, 64.2			

It is practically impossible to arrange a set scale of percents that will show the exact value of each kind, on account of varying circumstances surrounding the fences. For example, one fence may contain posts of the very best quality of their kind while another of another kind may contain a second best. Then there are all stages of seasoning, and different kinds of soil. Then, too, the age of a fence and the percent of rotten posts do not increase at the same rate.

While, therefore, in the tables above, the average age and the average percent sound cannot be regarded as scientifically accurate, yet it is felt that they give a fair idea of the durability of the various kinds.

In the following table an effort is made to picture the relative value of the different kinds of timber by giving the percent of posts that are usually found to be sound at various ages, beginning at ten years and counting each five succeeding years up to 50 years.

When the number of sound posts falls below 50 percent, no further notice is made of it.

This table probably shows the best comparative estimate that can be given.

PERCENTAGE OF SOUND POSTS IN AVERAGE FENCES
AT AGES FROM TEN TO FIFTY YEARS

Age in Years	Osage Orange	Locust	Red Cedar	Mul- berry	White Cedar	Catal- pa	Chest- nut	Oak	Black Ash
10.....	100	100	100	97	85	90	72	71	40
15.....	100	95	97	80	78	72	62	61	
20	100	89	87	78	62	58		47	
25.....	100	(86)	(84)	73	65	53		62	
30....	99	83	80	62		45			
35.....	98	(79)	55	85		50			
40.....	97	83	70						
45	100								
50.....	100								

The numbers in parentheses are in part or entirely estimated from the numbers preceding and following; for example, it so happened that there were no locust fences examined that were exactly 25 years old, and the percent sound for this age is estimated at 86, which is half way between 89 and 83, the percentage for 20 and 30 years respectively.

It will be noticed that in each column the numbers representing the percentage of sound posts decrease to a certain point and then increase again; for example, the column under "Red Cedar" decreases until age 35 is reached. We find the average fences at this age are 55 percent sound, while the average fences at 40 years of age are 70 percent sound.

The cause of this unexpected feature is that the posts are large and of exceptionally fine quality with practically no defective posts. The important part of the table is that before this increase in percentage takes place and for this reason the first or important part is printed in bold face type.

Fences of these older ages have been found as recorded, and although they are not the types that estimates should be made from, yet it was thought best to put them in the table, but they have been put in with a different kind of type. One very important lesson that they teach is the effect brought about by the selection of good quality of perfectly sound timber.

It will be seen from the table that the Osage orange is in a class entirely alone, with no close competitor. Yellow locust and red cedar come next, very close together, with a little in favor of the locust. In the case of the red cedar, only that which grew in the woods is counted. That which grows in the open is about the same as oak in durability. Considerably below these two is mulberry. Then white cedar and catalpa quite close together; and below these, chestnut and oak, with a little in favor of chestnut; then black ash. The varieties of oak counted are white oak, chinquapin oak, burr oak, the majority being white oak. A small amount of black oak and post oak has also been examined.

Besides these varieties there have been found a few at a place of honey locust, sassafras, black walnut, white walnut and elm. The durability of these is usually poor; though some instances of excellent durability have been found in the black walnut. It is regularly poor when cut from a thrifty young tree.

The durability of some timbers seems to have been over estimated; for example, the chestnut and the hardy catalpa, especially the latter.

The author is aware that most writers on this subject class the hardy catalpa with the red cedar, the yellow locust, and the Osage orange, but the examination of 292 fences containing 30,160 posts in actual service points to the conclusion herein made, and the classification has been made in accordance with what the data indicate, regardless of any personal opinion. The fences examined were the oldest that could be found.

It is suggested that the former estimate placed on the durability of this timber seems to have been taken in a large measure from isolated posts, from old logs pulled out of river beds where they had lain for many years, or from railroad ties where no record is given of those that may have rotted in the same track while these survived. A dozen ties that have survived 25 or 30 years in the road-bed of a railroad are worth but little for data unless it is known how many of the same kind rotted in the same situation. A dozen posts that have survived 40 years in a fence are worth but little for data, unless we know the condition of all the other posts in the same fence.

Let us illustrate with a timber that we are all acquainted with. Near Albion, Illinois, there is a gate post that was an old weather-beaten post when the present owner bought the farm, just before the Civil War. This post was still supporting a gate in the summer of 1906. Near Lebanon, Ohio, is a post which supported a gate, or gates, 65 years and was then run against by a two-horse wagon, owned by the grandson of the man who set the post. It stopped the wagon and was not broken. These two posts are white oak.

At the Ohio Experiment Station, at Wooster, Ohio, is a piece of white oak timber a foot square. This piece was one end of a log 60 feet long. The entire log is sound, showing practically no decay at any point. This log has been under ground ever since the Wabash Canal was built. It was under water most of the time.

It is evident that an estimate of the durability of white oak should not be made from these three instances.

The fact should be kept very clearly in mind that *in order to have reliable data, we should have a number of fences with a considerable number of posts in each, and the condition of every post in the fences should be taken.* It would be just as fair to gather up the rotten ones and make an estimate from them alone, as to take the sound ones that have survived and make no note of the rotten ones



Plate VIII. Parts of two Osage orange posts, from two fences, one 30 and the other 34 years old. Each fence contains a little over 99 percent sound posts. This is about an average for the Osage orange. The pieces marked X are the parts that were in the ground. See page 620.



Plate IX. The trunk of a healthy young locust tree. Note the lighter colored places between the longitudinal ridges.



Plate X. The trunk of a locust tree affected with the locust borer. Notice the lumpy, uneven surface and that the bark is all dark. Compare this with Plate IX.

SOME FACTS BROUGHT OUT BY THIS INVESTIGATION

1. That a large post usually lasts longer than a small one of the same wood.

2. That there is no difference which end is put in the ground, except that the sounder or larger end should have the preference.

3. In stiff clay soil, the posts rot principally just beneath the top of the ground, and in a porous sandy or gravelly soil, they usually rot from the top of the soil all the way down; the effect is the same in both cases.

4. In soil that is full of water all the time, posts will last longer. It is the alternating between wet and dry that causes decay.

5. From data collected so far, seasoning does not seem to have any marked effect on durability. The best catalpa fence examined was set green; cf. catalpa fence No. 8. In the best oak fence examined, the posts were cut and put in the ground the same day; cf. oak fence No. 14. Likewise some of the best fences are those in which the posts were well seasoned.

It has been very difficult to get accurate data on the matter of seasoning, especially in fences where the posts have been only partially seasoned when set. But there has been a sufficient number found, in which the posts when set were well seasoned or entirely green, to justify the above conclusion. We hope, however, to be able to investigate this matter further.

6. Timber that grows rapidly and in the open is not as good as the same variety that grows in the woods. This has been observed especially in the red cedar, the catalpa, and the locust. Compare red cedar fence No. 2, 11 years old and 74 percent sound with red cedar No. 15, 40 years old and 75 percent sound; No. 2 is from rapid and No. 15 is from slow growing timber. Compare catalpa fence No. 2, 11 years old, all rotten: No. 12, 5 1-2 years old, 25 percent sound; No. 28, 16 years old, 9 percent sound; No. 72, 6 1-2 years old, 64 percent sound with catalpa No. 8, 31 years old, 88 percent sound; No. 13, 15 years old, 86 percent sound; No. 22, 25 years old, 67 percent sound. Compare locust No. 4, 6 1-2 years old, 82 percent sound with locust No. 9, 21 years old, 91 percent sound. See Plates III, IV, V, VI and VII.

7. There is some evidence that it is not a good time to cut posts just as the tree begins to grow in early spring. This was noticed especially in catalpa fences Nos. 12 and 25 and to some extent in a number of others.

8. The wood at the center of the tree is not as good as that just inside the sap wood. This characteristic is very common with nearly all the varieties of timber examined, especially so with the locust, the white cedar, the hardy catalpa, and the oaks. See Plates I and II.

9. The quality of the wood or the condition of the wood fiber of a post is a very important item in its ability to endure in the soil. In an average lot of so-called first class posts on the market, usually a number can be selected that are defective, though they may appear sound and firm. This quality of post is usually somewhat darker than the usual color, especially near the center of the tree.

At the State Experiment Station at Wooster, Ohio, there are on file the data of every fence that was examined in this investigation. These data contain, among other items, the name and address of the owner, the location of the fence on the farm, and the date the fence was examined. Any one who feels inclined to examine any of these fences that happen to be in his community can get their location by writing to the Forestry Department of the Experiment Station.

BULLETIN

OF THE

Ohio Agricultural Experiment Station

NUMBER 220

JULY, 1910

METEOROLOGICAL SUMMARY—PRESS BULLETINS— INDEX.

METEOROLOGICAL SUMMARY FOR 1909.

BY C. A. PATTON.

EXPLANATION OF TABLES.

The following tables contain statistics of temperature, rainfall, etc., for the year, and are compiled from data obtained from daily observations. T stands for "trace"—less than .01 inch of rainfall. Temperature is given in degrees Fahrenheit.

Table I shows the daily rainfall at the station during the year in inches and hundredths.

Table II shows the daily mean temperature for each day of 1909 and the monthly mean temperature with the 22 years' average.

Table III gives the monthly mean temperature at the station with the 22 years' average for the same.

Table IV gives the monthly mean rainfall for the station with the 22 years' average for the same.

Table V gives the monthly mean temperature for the state for 1909 with the 22 years' average.

Table VI gives the monthly mean rainfall for 1909 with the 22 years' average for the state.

Table VII gives the monthly mean temperature and rainfall for the station and state for 1909 with the 22 years' average.

Table VIII contains the mean temperature, the highest and lowest temperatures, with the range of temperature for each month; the number of clear, fair and cloudy days; the rainfall, snowfall and prevailing direction of wind, for both the station and state for 1909.

Table IX contains the principal points of interest on temperature, rainfall, and state of weather at the station during the year, and a grand summary for twenty-two years.

Table X contains the principal points of interest on temperature, rainfall, and state of weather for the state during the year and a grand summary for twenty-seven years.

Table XI gives the highest and lowest temperature for each month during the past twenty-two years, for both the station and state.

NOTES ON THE WEATHER AT THE STATION, 1909.

SUMMARY BY MONTHS.

LATITUDE $40^{\circ} 47' 01''$, LONGITUDE $81^{\circ} 55' 48''$.

ELEVATION ABOVE THE SEA 1,030 FEET.

JANUARY.

The mean temperature for January was 31.7° , which is 4.3° above the station average for January. The highest, 66° , occurred on the 24th; the lowest, 11° , on the 13th. Cloudy weather prevailed. Rain or snow fell on twelve days. The total precipitation was 2.95 inches, which is .21 inch below the station average for January. The prevailing wind was southwest.

FEBRUARY.

The mean temperature for February was 33.6° , which is 7.1° above the station average for February. The highest, 60° , occurred on the 24th; the lowest, -2° , on the first. Cloudy weather prevailed. Rain or snow fell on seventeen days. The total precipitation was 5.22 inches, which is 2.36 inches above the station average for February. The prevailing wind was southwest.

MARCH.

The mean temperature for March was 35.9° , which is 1.3° above the station average for March. The highest, 60° , occurred on the 9th; the lowest, 12° , on the 17th. Cloudy weather prevailed. Rain or snow fell on sixteen days. The total precipitation was 3.02 inches, which is .52 inch below the station average for March. The prevailing wind was northwest.

APRIL.

The mean temperature for April was 48.4° , which is $.4^{\circ}$, above the station average for April. The highest, 81° occurred on the 18th; the lowest, 13° on the 10th. Cloudy weather prevailed. Rain or snow fell on twelve days. The total precipitation was 3.92 inches which is 1.10 inches above the station average for April. The prevailing wind was southwest.

MAY.

The mean temperature for May was 57.9° which is $.5^{\circ}$ below the station average for May. The highest, 84° occurred on the 31st; the lowest, 31° on the 11th. Fair weather prevailed. Rain fell on twelve days. The total precipitation was 4.06 inches, which is .04 inch above the station average for may. The prevailing wind was north.

JUNE.

The mean temperature for June was 69.3° which is 1.6° below the station average for June. The highest, 89° occurred on June 27th; the lowest, 42° on the 19th. Rainy weather prevailed. Rain fell on seventeen days. The total precipitation was 6.44 inches, which is 2.28 inches above the station average for June. The prevailing wind was northeast.

JULY.

The mean temperature for July was 69.6° which is 1.6° below the station average for July. The highest, 89° occurred on the 12th; the lowest, 45° on the 4th. Clear weather prevailed. Rain fell on eleven days. The total precipitation was 4.05 inches, which is .25 inch below the station average for July. The prevailing wind was south and northeast.

AUGUST

The mean temperature for August was 70.4° which is 1.1° above the station average for August. The highest, 89° occurred on the 8th; the lowest, 41° on the 22nd. Clear weather prevailed. Rain fell on ten days. The total precipitation was 5.21 inches, which is 1.83 inches above the station average for August. The prevailing wind was south.

SEPTEMBER.

The mean temperature for September was 62.2° which is 1.6° below the station average for September. The highest, 90° occurred on the 14th; the lowest, 30° on the 28th. Clear weather prevailed. Rain fell on seven days. The total precipitation was 1.73 inches, which is 1.44 inches below the station average for September. The prevailing wind was northeast and southwest.

OCTOBER.

The mean temperature for October was 47.8° which is 3.1° below the station average for October. The highest 81° occurred on the 9th; the lowest, 22° on the 29th. Cloudy weather prevailed. Rain or snow fell on six days. The total precipitation was 2.16 inches which is .12 inch below the station average for October. The prevailing wind was northeast.

NOVEMBER.

The mean temperature for November was 48.3° which is 8° above the station average for November. The highest, 72° occurred on the 13th; the lowest, 21° on the 24th. Cloudy weather prevailed. Rain or snow fell on ten days. The total precipitation was 2.91 inches which is .08 inch above the station average for November. The prevailing wind was south.

DECEMBER.

The mean temperature for December was 25.2° which is 5.3° below the station average for December. The highest, 66° occurred on the 5th; the lowest— 6° on the 30th. Cloudy weather prevailed. Rain or snow fell on fourteen days. The total precipitation was 2.55 inches which is .08 inch below the station average for December. The prevailing wind was southwest.

METEOROLOGY—TABLE I—RAINFALL

DAILY RAINFALL AND MELTED SNOW FOR 1909 AT EXPERIMENT STATION

Date	January	February	March	April	May	June	July	August	September	October	November	December	Date
1.....	T		.05		T	.70	.05				.05		1
2.....			T		T						.34		2
3.....	.14		.22	.16	.09	.95			.10		.02		3
4.....	.14		.25	.06	.03	.15			.35			.02	4
5.....	.30	.30						.32					5
6.....	T	.15	T	.75							.19	.06	6
7.....	T		.30	.04		.08						.32	7
8.....						.23					.32	T	8
9.....	T	.48	.72	.05	.50	.13		.02	T			T	9
10.....	.13	.08	.05	.17	1.06	.25			.04				10
11.....	.10	T	T		.02		.20			.50		.05	11
12.....	.40	.05					.51	.08		.13	T	.20	12
13.....	.30	.24		.18		.25	.14					.99	13
14.....	.02	.76	T	T	T	.07	.02	.11				.05	14
15.....		.26	.02		.11			2.09	.80	T	T		15
16.....	.15	.10	.05		.24		.87	.11		T	.52		16
17.....	T	T	.25			.69					.28		17
18.....							.01	.02		.16	T	.02	18
19.....		.60	.28	T							T		19
20.....		.05		.08	.45			T					20
21.....		.05		.40	.60	.57				.20	.33	.10	21
22.....	T			T		.34	.13		T		.49	T	22
23.....	.53	1.16				.16	.18		.21	1.02	.37	.02	23
24.....		.74	.22			.04	T		.08	.15		.02	24
25.....		.10	.46			.02						.50	25
26.....			.01					.70		T		T	26
27.....		T	.02	.28	.51	1.71	.24					.10	27
28.....		.10				.10		1.72				.10	28
29.....	.34		.10	1.03			1.70	.04	T			T	29
30.....	.40		.02	.72	.03				.15				30
31.....	T				.42		T						31
Totals.....	2.95	5.22	3.02	3.92	4.06	6.44	4.05	5.21	1.73	2.16	2.91	2.55	
Averages....	.095	.186	0.97	.130	.131	.215	.131	.168	.058	.070	.097	.082	

METEOROLOGY—TABLE II—TEMPERATURE
MEAN TEMPERATURE FOR EACH DAY OF 1909 AT THE STATION.

Date	January	February	March	April	May	June	July	August	September	October	November	December	Date
1.....	21.0	9.0	33.0	38.5	47.5	71.5	72.0	73.0	59.0	49.0	57.5	49.5	1
2.....	27.0	25.5	39.5	43.5	44.5	64.5	71.5	72.5	55.0	47.5	55.0	40.5	2
3.....	39.5	33.0	35.0	40.0	43.5	67.0	66.5	72.5	61.5	50.0	45.0	38.0	3
4.....	45.0	40.5	27.5	41.5	44.5	73.5	58.0	70.0	63.5	49.5	45.5	44.5	4
5.....	43.5	50.5	26.5	57.5	57.5	68.5	64.0	73.5	61.5	53.5	40.0	53.0	5
6.....	25.0	42.0	41.0	61.5	72.0	66.0	70.5	71.5	55.0	54.0	46.0	39.5	6
7.....	14.0	31.5	43.0	53.5	64.0	69.0	66.5	71.5	58.5	56.5	51.5	34.5	7
8.....	21.0	34.0	36.0	43.5	53.5	64.5	67.0	77.5	63.5	57.5	54.0	19.5	8
9.....	31.5	36.5	48.5	35.0	68.0	69.5	69.5	76.0	67.5	59.5	46.5	8.5	9
10.....	40.0	33.0	44.0	22.0	49.5	68.5	72.5	68.5	72.0	60.0	54.0	17.0	10
11.....	33.5	23.5	31.5	34.5	44.5	64.5	73.5	66.0	66.5	54.5	59.5	21.5	11
12.....	12.5	37.0	33.5	56.0	50.0	61.5	77.5	68.5	66.5	43.0	58.0	31.0	12
13.....	4.5	37.5	40.0	52.0	60.0	70.0	74.0	73.0	72.5	38.0	61.0	38.5	13
14.....	29.5	41.5	34.5	39.5	67.0	70.5	72.5	73.0	76.0	46.5	61.5	31.5	14
15.....	33.5	29.5	32.0	41.5	73.0	62.5	75.5	74.0	71.5	40.5	53.5	29.0	15
16.....	25.0	21.5	31.0	56.0	63.0	63.0	71.5	74.5	63.0	42.0	51.0	24.0	16
17.....	26.0	21.5	22.5	62.5	58.0	66.0	67.0	69.5	61.5	42.0	45.0	25.5	17
18.....	19.5	32.0	29.0	64.5	53.5	56.0	67.0	67.0	61.0	42.5	42.5	19.5	18
19.....	22.0	43.0	43.5	57.5	54.0	59.5	59.5	70.5	67.0	38.5	39.5	12.5	19
20.....	31.0	37.0	38.0	42.0	57.0	66.0	63.0	67.0	72.0	46.0	50.0	15.0	20
21.....	39.5	33.5	34.0	57.0	55.5	74.5	71.5	61.0	67.5	59.0	47.0	20.5	21
22.....	53.0	37.5	30.0	50.5	57.5	74.5	73.5	60.0	73.5	53.5	57.0	16.0	22
23.....	54.0	45.5	33.0	43.5	53.0	77.0	64.5	63.5	65.0	42.0	49.0	19.0	23
24.....	61.5	46.0	39.0	52.0	55.0	77.0	64.0	70.0	58.0	36.5	31.0	18.5	24
25.....	48.0	25.5	40.0	54.0	56.5	74.5	66.5	76.0	53.0	38.0	31.0	24.5	25
26.....	34.0	32.5	35.0	45.0	65.0	76.0	68.5	77.0	48.0	49.5	38.8	25.5	26
27.....	36.5	35.5	43.0	51.0	69.0	79.0	70.5	76.0	50.0	49.0	45.0	19.0	27
28.....	38.0	26.0	39.5	40.5	59.0	77.5	75.5	74.0	47.5	39.0	52.0	15.5	28
29.....	35.0	.....	38.0	54.5	65.0	76.0	77.0	72.0	59.5	35.0	45.5	10.0	29
30.....	24.5	.....	36.5	61.0	63.5	70.5	77.5	61.0	49.5	51.0	35.5	4.0	30
31.....	14.5	.....	37.5	.....	71.5	.....	71.0	61.0	.....	55.0	.....	18.5	31
Monthly mean	31.7	33.6	35.9	48.4	57.9	69.3	69.6	70.4	62.2	47.8	48.3	25.2	
22-year ave.	27.4	26.5	37.2	48.0	58.4	67.7	71.2	69.3	63.8	50.9	40.3	30.5	

METEOROLOGY—TABLE III

MONTHLY MEAN TEMPERATURE FOR TWENTY-TWO YEARS AT WOOSTER.

Temperature in degrees Fahrenheit.

Date	January	February	March	April	May	June	July	August	September	October	November	December	Year	Date
1888.....	23.0	28.8	31.7	46.3	57.7	68.9	70.1	67.8	57.1	44.9	40.7	31.4	47.3	1888
1889.....	31.1	22.9	38.7	47.1	57.8	64.5	70.0	66.0	66.8	45.3	39.3	40.7	48.6	1889
1890.....	36.0	36.6	30.9	48.4	56.0	69.8	70.5	65.8	59.6	50.0	41.3	28.8	49.5	1890
1891.....	30.0	34.0	32.0	49.0	52.0	68.0	68.0	71.0	68.0	49.0	38.0	37.0	49.6	1891
1892.....	22.0	33.0	33.0	47.0	57.0	70.0	70.0	69.0	61.0	49.0	38.0	28.0	46.0	1892
1893.....	18.0	28.0	38.0	50.1	57.6	69.3	72.0	67.9	63.2	52.3	37.7	30.9	48.7	1893
1894.....	32.8	26.7	43.5	50.5	57.5	67.9	71.4	69.2	66.1	52.3	36.5	32.9	50.6	1894
1895.....	21.9	17.9	32.4	49.5	59.4	69.9	68.6	70.9	66.5	44.2	40.4	32.8	47.8	1895
1896.....	27.9	29.2	29.8	54.6	64.5	65.6	70.2	68.5	60.6	45.8	44.4	30.6	49.3	1896
1897.....	24.0	30.0	39.3	47.2	53.4	64.3	73.2	67.0	66.7	55.9	40.7	31.8	49.4	1897
1898.....	31.6	27.4	43.3	45.3	58.2	68.7	74.5	71.1	66.2	52.6	38.4	27.9	50.4	1898
1899.....	26.6	21.3	35.0	52.1	60.0	69.4	70.0	71.0	61.6	55.0	43.2	29.0	49.5	1899
1900.....	30.2	25.0	31.8	47.8	61.5	68.5	72.6	74.0	67.1	58.9	40.6	30.7	50.7	1900
1901.....	28.3	20.0	39.1	45.2	57.9	69.1	75.9	71.6	63.3	51.7	36.6	26.1	48.7	1901
1902.....	26.3	21.4	41.2	46.2	61.2	65.6	73.0	66.4	62.7	53.9	47.3	28.7	49.5	1902
1903.....	24.4	29.0	45.7	48.0	62.2	63.0	71.8	68.8	64.4	58.2	36.8	21.7	49.1	1903
1904.....	18.6	20.5	37.6	42.8	59.4	67.0	69.8	66.7	64.2	50.4	39.6	28.1	47.1	1904
1905.....	22.6	19.8	41.2	46.8	59.2	68.0	71.6	70.0	63.8	51.0	38.3	33.1	48.8	1905
1906.....	35.9	25.8	30.2	51.9	59.9	68.8	71.0	74.2	67.7	51.4	40.4	31.2	50.7	1906
1907.....	30.8	24.6	44.9	41.7	52.8	64.6	69.9	68.6	65.0	47.4	38.5	32.1	48.4	1907
1908.....	28.7	26.8	43.1	50.1	62.2	68.1	72.4	69.0	66.4	53.0	41.0	31.7	51.0	1908
1909.....	31.7	33.6	35.9	48.4	57.9	69.3	69.6	70.4	62.2	47.8	48.3	25.2	50.0	1909
Average..	27.4	26.5	37.2	48.0	58.4	67.7	71.2	69.3	63.8	50.9	40.3	30.5	49.3	

METEOROLOGY—TABLE IV
MONTHLY RAINFALL FOR TWENTY-TWO YEARS AT WOOSTER
Rainfall—Inches

Date	January	February	March	April	May	June	July	August	September	October	November	December	Year	Date
1888.....	3.52	2.43	3.34	2.48	3.82	2.31	4.54	4.35	1.92	3.18	4.95	1.39	3.18	1888
1889.....	4.33	2.42	2.13	1.58	2.97	4.86	6.73	1.98	4.05	1.36	3.53	3.93	3.32	1889
1890.....	4.71	6.20	4.37	3.10	6.01	5.57	2.67	4.66	5.12	7.45	2.61	1.74	4.51	1890
1891.....	2.74	4.83	3.71	1.66	2.24	7.13	3.28	1.85	0.94	1.33	5.73	2.92	3.20	1891
1892.....	2.67	2.67	3.38	2.44	7.69	7.89	4.73	2.69	3.20	0.37	2.06	1.74	3.46	1892
1893.....	4.01	6.33	1.89	5.66	6.28	2.51	1.38	1.53	1.85	5.18	2.49	1.50	3.38	1893
1894.....	2.19	3.37	2.36	1.74	4.41	2.23	1.38	0.76	4.07	2.53	2.41	3.15	2.55	1894
1895.....	3.92	1.00	1.98	1.69	1.38	4.20	2.19	2.30	3.92	1.15	4.21	3.51	2.65	1895
1896.....	1.73	2.27	3.67	3.34	3.41	3.98	8.05	1.96	5.16	0.71	1.78	2.41	3.21	1896
1897.....	2.82	2.64	2.81	2.75	4.97	2.98	3.89	3.86	0.29	0.89	5.76	2.50	3.01	1897
1898.....	4.10	2.27	6.44	2.56	4.60	2.70	6.79	5.53	2.15	4.25	4.14	2.29	3.99	1898
1899.....	3.29	1.64	3.95	1.28	4.42	1.95	3.73	0.53	5.56	2.21	1.59	2.78	2.74	1899
1900.....	2.78	2.74	2.25	1.70	2.23	3.71	5.65	5.97	2.19	2.10	4.30	0.99	3.05	1900
1901.....	1.58	1.20	3.09	2.46	4.32	4.82	3.32	3.58	5.64	0.81	1.62	3.47	2.99	1901
1902.....	0.63	0.83	2.99	1.46	2.57	5.55	5.26	1.87	3.49	1.52	2.62	4.07	2.74	1902
1903.....	3.54	3.69	3.29	4.55	1.59	3.69	4.61	6.58	2.07	2.63	2.25	1.95	3.37	1903
1904.....	5.27	3.90	6.22	6.59	4.45	1.67	4.93	2.03	2.27	0.87	0.40	2.68	3.44	1904
1905.....	1.83	1.36	2.61	2.51	5.97	7.50	5.14	4.47	5.10	2.32	2.04	2.08	3.58	1905
1906.....	1.93	1.06	3.57	2.27	2.98	3.81	4.93	7.38	5.16	3.55	2.39	3.77	3.57	1906
1907.....	6.92	1.09	5.80	2.69	3.48	3.81	3.96	2.04	3.13	2.34	1.33	3.41	3.33	1907
1908.....	1.96	3.89	5.02	3.64	4.56	2.17	3.44	3.17	0.73	1.22	1.0 ⁹ ₁	3.05	2.83	1908
1909.....	2.95	5.22	3.02	3.92	4.06	6.44	4.05	5.21	1.73	2.16	2.9	2.55	3.68	1909
Average ...	3.16	2.86	3.54	2.82	4.02	4.16	4.30	3.38	3.17	2.28	2.83	2.63	3.26	

METEOROLOGY—TABLE V

MONTHLY MEAN TEMPERATURE FOR TWENTY-TWO YEARS FOR THE STATE

Temperature in degrees Fahrenheit

Date	January	February	March	April	May	June	July	August	September	October	November	December	Year	Date
1888.....	24.3	30.5	34.2	49.2	59.1	70.4	72.1	70.4	60.3	47.9	42.9	33.3	49.5	1888
1889.....	33.3	25.8	40.2	49.9	60.2	66.7	72.5	69.1	62.9	47.9	41.0	43.8	51.1	1889
1890.....	38.8	39.4	34.5	51.3	59.2	73.3	73.1	68.8	62.1	52.7	43.9	31.2	52.3	1890
1891.....	33.0	36.0	35.0	52.0	58.0	71.0	69.0	70.0	67.0	51.0	40.0	39.0	51.7	1891
1892.....	24.0	35.0	35.0	49.0	59.0	73.0	73.0	71.0	64.0	52.0	38.0	29.0	50.1	1892
1893.....	18.0	29.0	38.0	50.2	58.3	70.6	74.5	70.7	65.2	53.7	39.3	32.7	51.6	1893
1894.....	37.7	28.9	45.1	50.6	60.0	71.3	74.3	71.2	67.8	53.9	37.5	33.9	52.3	1894
1895.....	23.4	19.6	35.5	51.7	61.1	70.2	71.6	73.5	69.0	46.9	41.3	33.9	49.9	1895
1896.....	29.4	30.5	32.4	56.7	67.9	69.5	73.5	71.8	62.7	49.0	45.1	32.9	51.7	1896
1897.....	25.5	32.4	41.5	49.3	46.3	68.1	75.5	69.4	66.9	58.1	42.2	32.8	50.6	1897
1898.....	32.4	30.0	45.0	47.2	61.0	71.9	76.0	73.5	67.8	53.1	38.8	28.8	52.1	1898
1899.....	27.8	21.6	36.9	53.3	63.3	71.5	74.1	73.7	64.1	57.4	43.9	30.2	51.5	1899
1900.....	31.1	26.0	32.9	50.1	62.9	69.8	74.1	76.3	69.3	60.5	41.6	31.6	52.3	1900
1901.....	29.2	21.1	39.5	46.7	59.0	70.9	78.1	73.1	64.8	53.8	37.7	27.9	50.2	1901
1902.....	27.3	22.3	41.9	48.2	62.6	66.9	74.0	67.4	63.6	54.6	48.5	29.4	50.5	1902
1903.....	27.1	29.9	46.7	49.9	63.9	64.4	72.9	70.7	65.6	54.0	37.2	23.4	50.5	1903
1904.....	20.7	22.9	39.7	44.4	60.7	68.4	71.4	68.8	65.5	52.2	40.5	28.6	48.6	1904
1905.....	22.7	20.8	42.7	48.5	60.7	69.2	73.0	71.7	65.3	52.6	39.6	32.9	50.0	1905
1906.....	35.7	27.3	31.3	52.1	61.3	69.8	72.1	74.6	68.9	52.7	41.1	32.3	51.6	1906
1907.....	32.2	27.7	45.9	42.5	54.5	65.6	72.6	69.5	65.5	48.8	39.1	33.0	49.6	1907
1908.....	29.1	26.0	43.4	51.0	62.8	69.2	73.9	71.2	68.0	54.1	41.7	33.1	52.1	1908
1909.....	32.2	34.7	37.3	49.1	58.7	70.1	66.4	72.1	63.7	49.1	49.4	26.1	50.7	1909
Average	28.9	28.1	38.8	49.7	60.0	69.6	73.1	71.3	65.5	52.5	41.4	31.8	50.9	

METEOROLOGY—TABLE VI

MONTHLY RAINFALL FOR TWENTY-TWO YEARS FOR THE STATE

Rainfall—Inches

Date	January	February	March	April	May	June	July	August	September	October	November	December	Year	Date
1888.....	3.65	1.74	3.55	1.99	3.77	3.41	4.40	5.16	2.27	3.98	4.25	1.47	3.30	1888
1889	3.13	1.35	1.50	1.79	3.71	4.13	4.25	1.50	3.62	1.78	4.02	2.81	2.79	1889
1890	4.94	5.25	5.29	3.15	5.52	4.50	1.99	4.70	5.56	4.27	2.53	2.37	4.17	1890
1891	2.82	4.91	4.19	2.13	2.20	4.82	3.82	3.07	1.50	1.76	5.00	2.39	3.21	1891
1892	2.05	3.27	2.16	2.63	4.63	6.73	3.13	6.15	1.27	0.67	2.62	1.85	3.09	1892
1893	2.56	5.13	2.09	6.37	4.97	3.34	2.49	2.17	1.57	4.24	2.09	2.61	3.30	1893
1894	2.14	2.79	2.16	2.31	4.00	2.65	1.56	1.67	3.31	2.01	2.17	2.98	2.47	1894
1895	4.00	0.69	1.59	2.11	1.80	2.44	2.00	2.96	1.66	1.22	4.11	3.85	2.37	1895
1896	1.67	2.25	3.34	2.78	2.67	4.81	8.11	3.38	5.13	1.20	2.63	1.65	3.29	1896
1897	1.93	3.64	5.17	3.27	3.93	2.85	4.65	2.72	0.78	0.64	6.62	2.39	3.21	1897
1898	5.25	2.32	6.23	2.38	4.10	2.86	3.98	4.50	2.56	3.72	3.17	2.71	3.65	1898
1899	3.01	2.11	4.66	1.68	4.32	2.96	4.18	1.82	2.69	2.14	1.72	3.16	2.87	1899
1900	2.37	3.53	2.35	1.89	2.40	2.99	4.62	3.68	1.76	1.89	4.15	1.24	2.74	1900
1901	1.70	1.24	2.66	3.40	3.96	4.38	2.73	3.32	2.86	0.73	1.54	3.79	2.69	1901
1902	1.42	0.88	2.76	2.21	3.09	7.48	4.69	1.67	4.55	2.28	2.60	3.95	3.13	1902
1903	2.36	4.95	3.51	4.01	2.82	3.97	3.67	3.20	1.52	2.62	2.10	2.07	3.07	1903
1904	3.85	2.69	5.73	2.64	3.79	2.88	4.13	2.74	1.95	1.50	0.37	3.09	2.95	1904
1905	1.73	1.58	2.50	3.10	5.63	4.72	3.93	4.46	2.86	3.63	2.63	2.25	3.25	1905
1906	1.98	1.16	3.97	1.89	2.17	3.41	5.14	4.77	2.92	3.19	2.59	3.68	3.07	1906
1907	6.11	0.85	5.55	2.74	3.47	4.57	5.36	2.48	3.92	2.76	1.93	3.16	3.57	1907
1908	1.82	4.10	2.43	3.69	4.72	2.52	4.08	2.59	0.58	1.17	1.06	2.33	2.84	1908
1909	3.24	5.39	2.77	4.13	4.72	5.86	3.90	3.68	1.56	2.46	1.93	2.68	3.53	1909
Average...	2.90	2.81	3.60	2.83	3.74	4.01	3.95	3.29	2.56	2.27	2.81	2.66	3.12	

METEOROLOGY—TABLE VII.

MEAN TEMPERATURE AND RAINFALL FOR THE STATION AND STATE FOR 1909 AND FOR TWENTY-TWO YEARS.

Temperature in degrees Fahrenheit. Rainfall in inches.

	January	February	March	April	May	June	July	August	September	October	November	December	Year
Mean temperature at the Station, 1909.....	31.7	33.6	35.9	48.4	57.9	69.3	69.6	70.4	62.2	47.8	48.3	25.2	50.0
Twenty-two years' average temperature at the Station	27.4	26.5	37.2	48.0	58.4	67.7	71.2	69.3	63.8	50.9	40.3	30.5	49.3
Mean temperature for the State, 1909.....	32.2	34.7	37.3	49.1	58.7	70.1	66.4	72.1	63.7	49.1	49.4	26.1	50.7
Twenty-two years' average temperature for the State	28.9	28.1	38.8	49.7	60.0	69.6	73.1	71.3	65.5	52.5	41.4	31.8	50.9
Rainfall at the Station 1909	2.95	5.22	3.02	3.92	4.06	6.44	4.05	5.21	1.73	2.16	2.91	2.55	3.68
Twenty-two years' average rainfall at the Station	3.16	2.86	3.54	2.82	4.02	4.16	4.30	3.38	3.17	2.28	2.83	2.63	3.26
Rainfall for the State 1909	3.24	5.39	2.77	4.13	4.72	5.86	3.90	3.68	1.56	2.46	1.93	2.68	3.53
Twenty-two years average rainfall for the State	2.90	2.81	3.60	2.83	3.74	4.01	3.95	3.29	2.56	2.77	2.81	2.66	3.12

METEOROLOGY—TABLE VIII. SUMMARY BY MONTHS.

AT THE STATION	Temperature										Number of days				Precipitation in inches		Prevailing Wind		
	Mean	Highest	Date	Lowest	Date	Range	Mean daily range	Greatest daily range	Date	Least daily range	Date	Clear	Fair	Cloudy	Rainfall .01 in. or more	Monthly rainfall		Average daily rainfall	Monthly snowfall
January.....	31.7	66	24	-11	13	77	16.3	38	28	6	*16	1	5	25	12	2.95	.095	15.00	W.
February.....	33.6	60	24	-2	1	62	18.7	31	26	5	5	4	5	20	16	3.22	.186	5.25	W.
March.....	35.9	60	9	12	17	48	18.4	30	18	7	*4	5	6	20	17	3.92	.097	7.75	N. W.
April.....	48.4	81	18	13	10	68	24.6	37	29	8	20	7	3	20	12	3.02	.130	5.75	N. W.
May.....	57.9	84	31	31	*11	53	24.0	43	8	11	21	8	3	14	12	4.06	.131	....	N. E.
June.....	69.3	89	27	42	19	47	24.6	38	20	13	23	12	7	11	17	6.44	.215	....	S. E.
July.....	69.6	89	*12	45	4	44	23.7	35	9	11	23	18	10	3	11	4.95	.131	....	S. E.
August.....	70.4	89	*8	41	22	48	23.7	39	23	12	18	5	8	2	10	5.21	.168	....	S. E.
September.....	62.2	90	14	30	28	60	24.3	35	28	9	15	17	5	13	6	2.73	.058	....	N. E.
October.....	47.8	81	*9	22	29	59	24.8	43	9	5	24	13	5	13	6	2.16	.070	.25	N. E.
November.....	48.3	72	*13	21	24	51	20.6	36	*23	7	9	6	5	19	10	2.91	.097	.50	S. W.
December.....	25.2	66	5	-6	30	72	15.8	35	6	3	14	3	3	25	14	2.55	.082	9.75	S. W.
Sums and averages.....	50.0	77	..	20	..	57.4	21.4	36.7	..	8	..	114	76	175	144	3.68	.122	44.25	S. W.
FOR THE STATE																			
January.....	32.2	74	24	-17	13	91		49	12	1	..	6	7	18	13	3.24	.105	14.60	W.
February.....	34.7	70	23	-6	17	87		42	24	1	..	8	9	13	12	5.39	.192	5.10	W.
March.....	37.3	80	19	13	17	64		39	29	5	..	9	9	13	11	2.77	.089	3.60	W.
April.....	49.1	90	18	13	17	77		52	29	8	..	11	10	11	11	4.13	.138	1.00	W.
May.....	58.7	91	31	24	12	67		51	20	5	..	12	10	9	12	4.72	.152	1.10	W.
June.....	70.1	96	27	36	15	60		48	..	..	..	10	12	8	15	5.86	.195	....	W.
July.....	66.4	97	30	36	*2	61		46	..	..	..	14	11	7	10	3.90	.126	....	W.
August.....	73.1	96	*9	39	*22	57		52	..	..	..	18	10	4	6	3.68	.119	....	W.
September.....	62.7	96	13	25	23	61		52	..	..	..	16	8	6	8	1.56	.052	....	N.
October.....	49.1	86	*9	15	28	69		52	..	..	..	15	8	8	7	2.46	.079	T	W.
November.....	49.4	80	*14	15	24	65		50	..	..	..	15	9	10	8	1.93	.064	.28	W.
December.....	26.1	75	*5	-20	30	95		51	..	..	..	8	8	15	11	2.68	.086	10.20	W.
Sums and averages.....	50.7	85	..	13	..	71.9		48	..	..	..	137	110	121	124	3.53	.116	34.88	S. W.

*On other dates also.

METEOROLOGY—TABLE IX.

SUMMARY BY YEARS AND GRAND SUMMARY FOR TWENTY-TWO YEARS AT WOOSTER.

AT	1888	1889	1890	1891	1892	1893	1894	1895
	WOOSTER					EXPERIMENT STATION		
Mean temperature	47.3°	48.6°	49.5°	49.6°	48.°	48.7°	50.6°	47.8°
Highest temperature	91.5°	91.5°	94.5°	99.°	98.°	95.°	98.°	98.°
Lowest temperature	—5°	—5°	1.°	0.°	—20°	—9.°	—7.°	—6.°
Range of temperature	96.5°	96.5°	93.5°	99.°	118.°	104.°	105.°	104.°
Mean daily range of temperature	18.7°	18.7°	18.9°	21.°	19.°	20.2°	22.9°	21.8°
Greatest daily range of temperature	42°	42°	41.°	42°	46.°	45.°	45.°	55.°
Least daily range of temperature	2°	2°	4.5°	4.°	4.°	3.°	4.°	1.°
Number of clear days	125	125	109	116	116	96	127	125
Number of fair days	103	103	119	110	123	164	154	117
Number of cloudy days	137	137	137	125	98	105	84	123
Number of days's rain fell	119	119	149	119	119	129	130	102
Total yearly rainfall	38.23 inches	39.87 inches	54.21 inches	38.36 inches	41.46 inches	40.61 inches	30.60 inches	31.45 inches
Greatest monthly rainfall	6.75 in.	6.75 in.	7.45 in.	4.26 in.	7.89 in.	6.33 in.	4.41 in.	4.21 in.
Least monthly rainfall	1.39 inches	1.36 in.	1.74 in.	1.95 in.	1.37 in.	1.38 in.	0.76 in.	1.00 in.
Prevailing direction of wind	S.	S.	S.	S.	S. W.	S. W.	S. W.	W.

*1 July 10 and Sept. 1. *2 Feb. 23 and 24. *3 Jan. 8 and Sept. 10. *4 March 5, Nov. 1, 3 and 25, Dec. 1 and 18. *5 July 7, 25 and Sept. 7. *6 Jan. 24, Feb. 11 May 26. *7 Dec. 1 and 21.

METEOROLOGY—TABLE IX. Continued.
SUMMARY BY YEARS AND GRAND SUMMARY FOR TWENTY-TWO YEARS AT WOOSTER.

	1896	1897	1898	1899	1900	1901	1902	1903
	EXPERIMENT STATION							
Mean temperature	49.6°	49.4°	50.4°	49.5°	50.7°	48.7°	49.5°	49.1°
Highest temperature	93.° Aug. 9	96.° *10	96.° July 3	95.° Aug. 20	95.° July 4	95.° *12	97.° May 4	94.° *14
Lowest temperature	-6° Feb. 19	-18° Jan. 26	-9° Feb. 2	-21° Feb. 10	-10° Feb. 27	-11° Dec. 21	-9° Feb. 5	-9.° Feb. 19
Range of temperature	99.°	114.°	105.°	116.°	105.°	106.°	106.°	103.°
Mean daily range of temperature	19.°	21.5°	20.3°	22.9°	20.6°	20.1°	21.3°	21.6°
Greatest daily range of temperature	43.° May 8	49.° Oct. 5	50.° Nov. 14	52.° Oct. 24	43.° May 6	43.° April 30	45.° May 4	48.° Nov. 8
Least daily range of temperature	3.°	0.° Feb. 6	5.° *11	3.° Feb. 18	2.° Nov. 20	2.° April 20	4.° *13	3.°
Number of clear days	130	124	133	126	140	152	183	148
Number of fair days	106	123	104	114	140	165	49	98
Number of cloudy days	130	115	128	125	118	147	133	139
Number of days rain fell	134	123	134	116	132	142	140	121
Total yearly rainfall	38.47 inches	36.16 inches	47.85 inches	32.93 inches	36.61 inches	35.91 inches	32.86 inches	40.44 inches
Greatest monthly rainfall	8.05 in. July	5.76 in. Nov.	6.79 in. July	5.56 in. Nov.	5.97 in. Nov.	5.34 in. Nov.	5.53 in. June	6.58 in. Aug.
Least monthly rainfall	0.71 in. Oct.	0.29 in. Sept.	2.15 in. Sept.	0.53 in. Aug.	0.99 in. Dec.	0.81 in. Oc.	0.63 in. Jan.	1.59 in. May
Prevailing direction of wind	S. W.	S. W.	N. W.	N. S. W.	S. W.	S. W.	S. W.	S. W.

*8 Jan. 12, 13 and Feb. 5. *9 Jan. 10 and March 8. *10 July 5 and 6. *11 Jan. 21, March 2 and Dec. 18. *12 July 1, 22 and 28.

METEOROLOGY—TABLE IX—Concluded.
SUMMARY BY YEARS AND GRAND SUMMARY FOR TWENTY-TWO YEARS AT WOOSTER.

AT	1904	1905	1906	1907	1908	1909	Summary for twenty-two years
	EXPERIMENT STATION						
Mean temperature	47.1°	49.°	50.6°	48.4°	51.0°	50.0°	49.3°
Highest temperature	92° July 17	92.° July 17	92.° June 29	90.° Aug. 12	95.° *17	90.° Sept. 14	99.° Aug. 8 '91
Lowest temperature	—21.° Jan. 5	—12. Feb. 14	—14.° Feb. 7	—14° Jan. 27	—3° Feb. 9	—11 Jan. 13	—21° '19
Range of temperature	113.°	104.°	106.°	104.°	98.°	107.°	120°
Mean daily range of temperature	21.5°	20.8°	20.6°	20.8°	23.°	21.4°	20.8°
Greatest daily range of temperature	48.° Dec. 28	*16	40.° April 18	42.° Jan. 20	49.° Sept. 18	*18	55.° Oct. 6 '95
Least daily range of temperature	0.° Dec. 25	2.° Dec. 18	2.° Jan. 18	4.° Aug. 6	5.° Dec. 13	3.° Dec. 14	0.° *20
Number of clear days	149	144	136	109	141	114	131
Number of fair days	47	44	60	58	76	76	82
Number of cloudy days	170	177	175	198	147	175	134
Number of days rain fell	136	118	142	138	117	144	129
Total yearly rainfall	41.28 inches	42.93 inches	42.80 inches	40.00 inches	33.94 inches	44.22 inches	39.14 inches
Greatest monthly rainfall	6.59 in. April	7.50 in. June	7.38 in. Aug.	6.82 in. Jan.	5.02 in. Mar.	6.44 in. Jan.	8.05 in. July 1896
Least monthly rainfall	0.40 in. Nov.	1.36 in. Feb.	1.06 in. Feb.	1.09 in. Feb.	0.73 in. Sept.	1.73 in. Sept.	.29 in. Sept. 1897
Prevailing direction of wind	S. W.	S.	S.	N. S. W.	S. W.	S. W.	S. W.

*13 Jan. 22 and April 28. *14 July 4 and 9. *15 Jan. 4, Nov. 27 and Dec. 6. *16 April 9 and May 2. *17 Aug. 3, Sept. 24 and 25. *18 May 8 and Oct. 9. *19 Feb. 10. 1899 and Jan. 5, 1904. *20 Feb. 6, 1897 and Dec. 25, 1904.

*13 Jan. 22 and April 28. *14 July 4 and 9. *15 Jan. 4, Nov. 27 and Dec. 6. *16 April 9 and May 2. *17 Aug. 3, Sept. 24 and 25. *18 May 8 and Oct. 9. *19 Feb. 10 1899 and Jan. 5, 1904. *20 Feb. 6, 1897 and Dec. 25, 1904.

METEOROLOGY—TABLE X.
SUMMARY BY YEARS AND GRAND SUMMARY FOR TWENTY-SEVEN YEARS FOR THE STATE.

FOR THE STATE.	1883	1884	1885	1886	1887	1888	1889
Mean temperature.....	49.4°	50.6°	48.0°	49.6°	51.4°	49.5°	51.1°
Highest temperature.....	98.° Aug. 22	98.° *1	101.° July 21	98.6° July 7	108.° July 18	102.° Aug 3	99.5° Aug. 31
Lowest temperature.....	-17.2° Jan. 22	-34.° Jan. 25	-31.5° Jan. 29	-21.5° Jan. 12	-21.° Jan. 7	-15.° Jan. 27	-13.5° Feb. 24
Range of temperature.....	115.5°	133.°	132.°	120.1°	29.°	117.°	113.°
Greatest daily range of temperature.....	55.2° Mar. 18	50.° *2	58.5° Jan. 30	57.° Dec. 11	57.° Dec. 11	50.°	53.° Mar. 30
Average number of days rain fell.....	146	145	148	131	121	125	118
Mean yearly rainfall.....	44.98 inches	40.19 inches	39.08 inches	36.71 inches	33.63 inches	39.64 inch	33.53 inches
Mean daily rainfall.....	123 inch	110 inch	104 inch	100 inch	.062 inch	.108 inch	.092 inch
Prevailing direction of wind.....	S. W.	S. W.	S. W.	S. W.	S. W.	S. W.	S. W.
	1890	1891	1892	1893	1894	1895	1896
Mean temperature.....	52.4°	52.0°	50.0°	50.1°	52.4°	49.9°	51.8°
Highest temperature.....	103.1° Aug. 3	101.° Aug. 10	103.° July 25	102.° July 19	105.° *4	106.° July 20	103.° Apr. 17
Lowest temperature.....	-4.° Mar. 7	-8.° Mar. 2	-25.° Jan. 20	-24.° Jan. 11	-27.° Dec. 29	-24.° Feb. 6	-18.° *6
Range of temperature.....	107.1°	109.°	128.°	126.°	132.°	130.°	121.°
Greatest daily range of temperature.....	48.5° Apr. 11	50.° *3	51.° Sept. 25	54.6°	60.° Oct. 19	59.° *5	53.° Mar. 25
Average number of days rain fell.....	149	120	121	113	100	89	124
Mean yearly rainfall.....	50.33 inches	38.61 inches	37.16 inches	39.63 inches	29.75 inches	28.46 inches	39.58 inches
Mean daily rainfall.....	138 inch	.060 inch	102 inch	108 inch	.081 inch	.070 inch	.108 inch
Prevailing direction of wind.....	S. W.	S. W.	S. W.	S. W.	S. W.	S. W.	S. W.

*1 Sept. 23 and Oct. 1. *2 Sept. 5 and Dec. 4. *3 April 27 and 30. *4 July 18 and 19. *5 Jan. 15 and March 29. *6 Feb. 20 and 21.

METEOROLOGY—TABLE X.—Concluded.
SUMMARY BY YEARS AND GRAND SUMMARY FOR TWENTY-SEVEN YEARS FOR THE STATE.

FOR THE STATE.	1897	1898	1899	1900	1901	1902	1903
Mean temperature.....	50.6°	52.°	51.5°	52.°	50.2°	50.6°	50.5°
Highest temperature.....	113.° July 4	105.° July 1	105.° Sept. 6	103.° *8	108.° July 22	100.° July 8	104.° July 25
Lowest temperature.....	-27.° Jan. 26	-20.° Feb. 3	-39.° Feb. 10	-20.° *9	-20.° Feb. 23	-17.° Feb. 14	-20.° Feb. 19
Range of temperature.....	140.°	125.°	144.°	123.°	129.°	117.°	124.°
Greatest daily range of temperature.....	67.° *7	.....	.....	57.° Feb. 9	61.° Dec. 14	56.° May 4	60.° Sept. 25
Average number of days rain fell.....	110	121	107	107	107	114	111
Mean yearly rainfall.....	38.54 inches	43.78 inches	34.51 inches	32.87 inches	32.98 inches	37.58 inches	39.87 inches
Mean daily rainfall.....	.109 inch	.119 inch	.094 inch	.090 inch	.090 inch	.103 inch	.109 inch
Prevailing direction of wind.....	S. W.....	S. W.....	S. W.....	S. W.....	S. W.....	S. W.....	S. W.....
	1904	1905	1906	1907	1908	1909	Summary for 27 years
Mean temperature.....	48.6°	50.0°	51.6°	49.5°	52.1°	50.7°	50.7°
Highest temperature.....	99.° *10	100.° July 10	101.° Aug. 21	98.° July 22	104.° Aug. 3	97.° July 30	113.° July 4 97
Lowest temperature.....	-30.° Jan. 4	-20.° Feb. 3	-23.° Feb. 6	-19.° Feb. 6	-22.° Feb. 9	-20.° Dec. 30	-33.° Feb. 10 99
Range of temperature.....	129.°	120.°	124.°	117.°	126.°	117.°	152.°
Greatest daily range of temperature.....	54.° Jan. 5	57.° May 24	54.° Oct. 13	57.° Feb. 13	60.° Oct. 5	51.°	67.° Sept. 18 97
Average number of days rain fell.....	117	118	124	129	111	124	130
Mean yearly rainfall.....	35.36 inches	39.02 inches	36.87 inches	42.90 inches	34.09 inches	42.32 inches	37.52 inches
Mean daily rainfall.....	.096 inch	.107 inch	.101 inch	.117 inch	.092 inch	.116 inch	.101 inch
Prevailing direction of wind.....	S. W.....	S. W.....	S. W.....	S. W.....	S. W.....	S. W.....	S. W.....

*7 Sept. 25 and 26. *8 July 4, Aug. 6 and 10. *9 Jan. 20 and Feb. 27. *10 July 17 and Sept. 23.

METEOROLOGY—TABLE XI.
MONTHLY MAXIMUM AND MINIMUM TEMPERATURE FOR TWENTY-TWO YEARS—FOR WOOSTER.

DATE	January		February		March		April		May		June		July		August		September		October		November		December	
	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest
1888	54	-5	54	-1	71	8	80	19	90	31	42	92	43	90	41	92	31	76	27	65	21	65	9	
1889	66	12	65	-1	61	16	74	23	83	30	38	46	45	95	45	88	37	81	23	30	16	48	18	
1890	51	12	60	3	60	1	83	23	82	28	46	49	49	99	53	88	38	85	30	66	24	58	16	
1891	54	-20	54	6	65	10	76	28	86	38	56	48	48	98	49	95	42	81	25	67	10	61	12	
1892	51	-9	64	-2	75	10	83	24	84	36	92	45	47	93	37	95	36	85	24	66	15	62	7	
1893	56	-1	64	-1	75	14	92	24	83	35	37	98	41	96	41	93	36	80	28	65	31	57	2	
1894	54	-6	60	-6	59	9	80	21	94	27	98	35	92	93	42	93	34	73	19	69	18	61	1	
1895	53	-2	58	-6	65	4	89	19	86	44	37	96	45	93	41	92	34	71	21	65	13	56	2	
1896	61	-18	54	-9	69	11	79	16	78	31	88	37	96	50	92	42	96	25	25	65	12	60	1	
1897	64	-6	57	-10	71	9	77	21	81	32	90	40	94	45	95	46	90	26	24	66	22	56	2	
1898	55	-4	60	0	67	9	86	20	86	30	92	40	94	45	95	39	94	32	86	24	66	13	56	1
1899	54	-5	65	-1	67	9	78	20	89	25	90	44	95	50	94	49	89	34	79	26	69	18	64	11
1900	53	-4	63	-9	69	9	82	22	89	33	38	46	46	90	48	40	85	34	77	30	67	22	63	1
1901	60	-8	63	-9	76	13	83	24	97	29	39	46	46	93	43	43	89	32	77	27	72	24	64	11
1902	47	2	59	-9	69	9	83	19	89	27	88	41	94	42	90	42	89	31	79	26	71	9	49	2
1903	60	-21	57	-10	74	13	72	13	88	33	88	44	92	46	90	42	89	31	83	19	68	15	63	1
1904	69	-8	63	-12	79	10	77	23	82	31	89	38	92	50	90	46	87	36	74	23	61	16	52	13
1905	72	-6	65	-14	61	-5	80	21	86	29	92	47	88	46	91	48	90	44	82	22	72	23	58	9
1906	67	-14	50	-5	82	21	78	15	81	29	89	40	92	46	90	43	88	34	74	22	72	18	56	9
1907	57	6	60	-3	89	12	80	24	89	30	91	36	92	46	95	43	95	28	84	24	68	17	59	7
1908	66	-11	60	-2	60	12	81	13	84	31	89	42	89	45	89	41	90	30	81	22	72	21	66	-6
Extremes....	72	-21	65	-21	82	-5	92	12	97	25	98	35	98	40	99	37	98	28	92	19	72	6	66	-11

METEOROLOGICAL SUMMARY

659

METEOROLOGICAL—TABLE XI.—Concluded.
MONTHLY MAXIMUM AND MINIMUM TEMPERATURE FOR TWENTY-TWO YEARS FOR THE STATE.

DATE	January		February		March		April		May		June		July		August		September		October		November		December	
	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest	Highest	Lowest	Highest	Lowest	Highest	Highest	Lowest	Highest	Lowest	Highest	
1888	68	-15	69	-10	77	-6	92	12	91	23	102	34	97	42	102	35	92	26	80	22	81	17	63	1
1889	61	1	70	-14	82	10	86	15	96	26	92	38	98	47	100	40	99	28	83	17	77	9	73	3
1890	75	3	73	-1	69	-5	86	20	92	28	101	39	101	43	103	40	92	33	85	29	77	17	65	9
1891	65	25	74	2	74	6	96	15	93	25	98	40	95	41	101	39	99	36	93	20	76	8	70	12
1892	61	25	80	-1	80	6	90	14	99	28	101	47	103	40	99	45	96	34	89	20	76	7	72	7
1893	63	24	68	1	93	9	93	20	94	23	102	40	101	42	101	37	100	24	95	15	76	1	70	15
1894	66	16	76	-13	91	3	97	16	98	31	102	29	105	36	104	36	103	27	90	15	79	4	70	27
1895	62	19	78	-24	91	7	90	16	102	19	105	23	106	34	103	31	105	25	84	8	85	5	79	13
1896	70	27	72	-18	73	-7	92	11	99	36	98	31	102	39	102	35	100	25	85	17	79	7	67	15
1897	71	27	72	-9	82	5	92	11	91	25	102	31	113	44	101	38	105	25	97	17	76	8	67	7
1898	71	18	72	-20	84	5	87	10	92	29	99	39	105	38	100	40	102	38	96	20	76	2	67	18
1899	66	20	67	-39	76	0	84	9	96	28	102	36	105	41	104	39	107	26	94	20	79	18	69	7
1900	67	20	80	-20	84	-8	87	15	97	26	96	38	103	38	103	40	100	33	93	23	80	7	65	2
1901	67	10	66	-17	80	0	90	17	98	25	103	30	109	48	101	42	98	29	88	20	79	10	73	19
1902	73	11	66	-8	82	11	88	10	93	22	98	33	100	43	97	37	98	24	88	21	87	17	63	11
1903	73	13	69	-11	85	11	81	7	95	27	95	35	104	42	101	38	98	26	93	15	88	2	67	19
1904	70	-30	75	-20	86	-5	89	1	93	22	98	37	99	41	97	38	99	23	89	15	75	0	69	16
1905	65	17	54	-18	86	-1	81	8	95	26	99	44	100	44	96	41	95	30	92	20	71	10	58	2
1906	79	-23	72	-23	74	-12	91	18	94	24	100	34	98	43	101	43	98	36	91	18	82	14	68	19
1907	79	-8	66	-19	86	-2	86	10	96	24	96	36	98	37	96	40	93	29	88	19	71	11	69	15
1908	59	-8	66	-22	85	12	91	16	96	25	100	33	102	42	104	37	100	23	90	15	77	5	68	2
1909	74	-17	70	-17	70	6	90	13	91	24	96	36	97	40	96	35	94	25	96	16	80	15	75	-20
Extremes.....	79	-30	80	-39	96	-12	103	6	102	19	105	29	113	34	104	31	107	23	97	8	88	0	79	-27

PRESS BULLETINS

The following press bulletins have been issued during the year:

No. 304. July 5, 1909. HARVEST MITES, "JIGGERS" OR "CHIGGERS."

Last year, threshermen, harvest hands, workers in potteries, and apparently all classes of laborers who were obliged to handle straw in any way suffered intensely from the attacks of harvest mites or "jiggers." Horses, stabled under mows in which infested straw had been stored, were in many cases rendered frantic by the irritation caused by these minute insects. Weather conditions lately have been exceedingly favorable for the development of a similar or worse plague this season.

The young mites are of microscopic size, blood red in color and belong in the order of spiders. The immature larvae are provided with only six legs while the adults have eight. It is the larval forms which cause annoyance. "Jiggers" are abundant in bramble thickets and on low growth in woods and along streams. They often occur in immense numbers in grain straw, sometimes causing sickness, and even death has sometimes resulted directly or indirectly from their attacks.

The eggs are laid on the ground. The young, upon hatching, in the species which have been studied, attach themselves to insect hosts and draw their sustenance from these for a time, dropping off when full fed. It is probably a misjudged attempt to follow their usual habit of parasitism that induces them to burrow into the flesh of human beings and warm blooded animals, a proceeding which invariably results in their death.

Preventives and remedies: The Ohio Experiment Station recommends that so far as possible one should avoid sitting or lying in locations that are apt to be infested. Where exposure is unavoidable, dust flowers of sulphur into all the underclothes, especially into the stockings and inside the shoes. Threshermen should sift it into all their clothing and rub it over their bodies. Where infested straw must be stored in mows, dust the floor with sulfur and thoroughly sift it over the first layers of straw placed on the floor. Napthaline powder may be used instead of sulfur and is said to be equally effective, but the odor makes it more objectionable. As soon as possible after quitting work, exposed persons should take a bath in strong soapsuds. The carbolic and tar soaps are very useful for this purpose. If the mites have already penetrated beneath the skin, bathe in a very strong suds of carbolic soap. A very effective wash for this purpose is to make a solution of one of the coal tar sheep dips, such as Zenoleum or Chloronaphtholeum, one part of the dip to a about 100 to 150 parts of water. Other solutions that may be used on the welts are of ammonia, coal oil (kerosene) or ordinary cooking soda. A dilute tincture of iodine or colloidion, if lightly applied to the swellings, will protect from the air and allay the smarting sensation. A complete change of clothing should be made after bathing.

No. 305. July 5, 1909. THE MINERAL ELEMENTS IN ANIMAL NUTRITION.

Bulletin 201, Ohio Agricultural Experiment Station, introduces students of agriculture to this important though somewhat unfamiliar subject.

That portion of plants and animals which will not burn, the ash or mineral substance, though slight in amount is exceedingly important. Every part of an animal contains mineral matter as an essential constituent, and every process in the life of animals involves these mineral substances.

The mineral nutrients are as important to the growth of plants as to the animals which use them for food. These minerals come from the soil. The amount and kind of fertility in the soil powerfully influences not only the *amount* but also the *kind* of growth, not only of plants grown upon the soil but also of the animals which use these plants as food.

Our most important stock feeding problem in the central United States is the most profitable use of corn. Corn happens to be particularly poor in mineral nutriment, especially so in calcium, the oxide of which we know as lime. Our most profitable use of corn demands that we consider not only proteid but also mineral supplements. The subject is of greatest importance as it relates to growing or milking animals generally and also to those raised most largely on corn, namely: hogs and poultry.

Many manufactured feeds are deficient in mineral nutrients and even pasture grass may be so deficient in minerals, especially in dry seasons and on certain types of soil, as to cause malnutrition of the bones of stock. The composition of foodstuffs affects the composition of bone, muscle, fat and visceral organs in the growth produced. The laxative character of feeds often depends upon the mineral constituents. Human foods are many of them deficient in minerals. Those human foods most deficient in mineral matter are rice, hominy, bolted cornmeal, patent flour, potatoes, sugar and fat meat. If one makes large use of these he should also use others containing much more mineral nutriment.

This bulletin may be had for the asking by addressing the Experiment Station at Wooster.

No. 306. July 19, 1909. FORAGE CROPS FOR EMERGENCIES.

Considerable areas in Ohio have recently been stricken by severe hail storms greatly injuring, and in some cases destroying the corn and oat crops. Many farmers are asking what may be done to relieve the situation. It is probable that in most instances the corn crop will send out new growth and make more feed than any new seeding would furnish.

While it is getting a little late to harvest a full crop of mid-summer forage crops it is yet worth while to seed the following crops:

Hungarian or Common millet—40 lbs. of seed per acre.

Sorghum—12 lbs. of seed in rows 36 inches apart.

Buckwheat—50 lbs. of seed per acre.

Rape—7 lbs. per acre.

Thick Corn, drilled solid or in rows.

No. 307. October 6, 1909. DO SOUTHWESTERN OHIO SOILS NEED LIME?

The correspondence of the Experiment Station indicates that some of the lands in Southwestern Ohio which have been longest in cultivation are in need of lime, notwithstanding the fact that this region is underlaid with limestone.

The first indication of lime-hunger in the soil is the behavior of the clover crop. The seed sown in the spring takes root and apparently a perfect stand is obtained. At harvest the land is fairly evenly covered with young clover, but there are patches, of greater or less extent, in which the plants seem unthrifty. As the season progresses these patches increase in size and the contrast becomes more apparent. By the following spring these patches are bare of clover, and weeds of various kinds, especially horse sorrel, have taken its place.

This unthriftiness of the clover usually makes its first appearance on the higher and dryer lands, and especially on those which have been long in cultivation with scanty manuring. It is also more apparent in dry seasons; in fact in a season of abundant rainfall throughout the summer it may not be observed, but the general tendency is towards an increasing difficulty in securing satisfactory crops of clover.

It should not be confused with complete destruction of the young plants by late spring frosts, nor with a disease of clover which causes a wilting and browning of the leaves and the appearance of black spots on the stems.

The Experiment Station is desirous of obtaining more definite knowledge on this point and to this end the request is made, that parties who may own or know of fields in which the conditions above described have been observed, will communicate with the Station and permit it to take a few bushels of soil for examination in its soil laboratories.

No. 308. November 15, 1909. PURCHASING SEEDS AND FRUIT TREES.

Many inquiries come to the Ohio Experiment Station regarding the best firms of which to buy fruit trees and seeds.

We have no means of knowing which firms are honest and which are not.

Most nurserymen and seedsmen try to keep their stock pure and the varieties true to name, but they often buy of others and mistakes may occur in handling. If nurserymen and seedsmen are to be censured more than other business men for lax methods, it is because they get stock from doubtful sources, by exchange or purchase, and because they so often take the liberty of substituting a variety which is "just as good" for the one ordered. Even if the Station could inspect twice a year the stocks of several hundred firms in the state, who deal in trees and seeds, it would not be possible to determine whether the varieties which are found growing were true to name. Much less would it be possible to arrive at any conclusion as to the results after exchanges have been affected by the dealers and substitutions made, so that orders may be filled.

The Station officials are cognizant of the fact that it is hard to find pure stocks of trees and seeds, for many varieties comes to it wrongly named.

There is no complete remedy for this state of affairs but it is a good plan to learn something of a man's reputation through his neighbors before buying trees of him. Then go early in the season and examine his trees. If an order is given specify that the trees must be of his own growing and that there *must be no substituting*. If ordering from a distant firm select those who advertise in first-class periodicals and specify as before, *no substituting*.

No. 309. March 14, 1910. DOES FARM POULTRY PAY?

In January of this year eggs were retailing in Cleveland and in many other cities in Ohio at 55 cents per dozen. During much of the winter they were selling at 40 cents or higher. These prices almost prohibited the use of eggs as an article of food, and caused many consumers to jump at the conclusion that there was easy money in egg production.

Careful inquiry among a number of farmers would seem to indicate that not to exceed 5 percent of the hens were laying at all during these months of high prices, and that, had the producer received for his product the price paid by the consumer, he would still, in many cases, have been a loser. Certain farms reporting to the Ohio Experiment Station, at Wooster, show an egg cost of from 7 to 13 cents each for the month of January. This does not argue that the poultry enterprise on these farms is an unprofitable one as a whole, for the entire year would have to be considered before arriving at a conclusion regarding this; whereas, no data are as yet available for consideration in this connection.

The Experiment Station is, however, conducting an investigation along this line in cooperation with an increasing number of farmers and poultrymen throughout the State and will doubtless secure data which will have a very distinct bearing upon the cost of living. The value of work of this kind can scarcely be overestimated. All accurate information regarding the cost of production will serve to bring the producer and consumer closer together.

No. 310. March 21, 1910. ARE WE GROWING THE BEST VARIETIES OF CORN IN THIS COUNTY?

The Ohio Experiment Station, in cooperation with the Ohio Corn Improvement Association, is making a study of the varieties of corn in Ohio. In 1909 fourteen counties had one or more county or township variety tests. The most of the varieties tested were those which some of the best farmers in that community were growing. The Experiment Station provided seed of some of the other best known varieties. Eighteen of these tests were carried through in such a way that the results are of scientific value.

The average yield of the poorest variety in these tests was 35.4 percent less than the average yield of the best variety. The two poorest varieties in each test averaged 30.2 percent lower than the two best. In eight of the tests the winning variety was a local one. In the other ten an outside variety led the list. In no case, however, was the winning variety from outside the State. Comparing the yield of the local varieties, the poorest was 27.1 percent less than the best.

The average yield of the State in 1909 was 39.5 bushels. The best and the poorest yielding varieties are both represented in this average. This being true, then if all the farmers in the State would grow the best variety, the State yield would surely be increased from 10 to 15 percent. Thirteen and five-tenths percent increase would amount to 5 1-4 bushels per acre or 15,000,000 bushels in total yield.

A large-plot variety test in any locality would be of much value to all the corn growers in that neighborhood. We would call this to the attention of our corn men. If arrangements cannot be made for such a test, then each progressive grower will certainly find it profitable to try at least one good variety in comparison with his own. If in doubt as to methods write to the Experiment Station at Wooster.

No. 311. March 28, 1910. EXAMINE YOUR SEED POTATOES FOR DRY-ROT. DISEASED SEED WILL GROW A DISEASED CROP.

Potatoes in Ohio, both early and late varieties, suffered severely in 1909 from premature dying due to *Fusarium* blight, which causes dry-rot in the tubers.

The Botanical Department of the Ohio Experiment Station wishes to warn growers so they may avoid the losses which might otherwise come from planting diseased seed potatoes. Aside from reduced yield or premature dying last year, every one needs to examine his seed tubers before cutting for planting. If potatoes for cooking are being used from similar stock, then the women of the household will find the disease wherever present.

The disease shows as dark or black spots running through the potato from the stem end. Usually the stem end of the potato, when diseased, will show a sunken appearance around the stem. In any case the dark spots show in the tubers when cut across near the stem end with a knife; in cases of bad infection, the black spots may run half way through the tubers. Where the infection is slight, it may occur only near the stem end. Of course, some of the tubers may be free from spots, and these are safe for planting on new land, but the disease lives over in the soil as well as in the tubers.

Where the disease has not penetrated more than one third of the length of the potato, the half of the potato toward the bud end may be used for seed with better promise. In such cases, the knife used for cutting should be dipped in a solution of corrosive sublimate, formaldehyde or carbolic acid after cutting diseased tubers, and before cutting others.

The point of this warning is to enable growers who have potatoes on hand, to examine at once and note whether their own seed is safe to plant. The usual seed treatment for scab, etc., will be very useful to kill dry-rot spores which may adhere to tubers, and may be applied to the healthy portions after separation from the diseased parts of potatoes.

Another reason for advanced warning, is the possible loss to the potato grower who has many bushels of stock on hand. These which show disease may be used to some advantage in feeding live stock after cooking. They have a fair value in this way for pig feeding.

If seed potatoes are to be bought, it is advisable to secure stock from northern points. Doubtless many northern potato regions have less disease than the more southerly ones. We have found very little in samples received from Red River Valley and from some parts of Michigan. The same may apply to northern New York and northern New England. *In all cases purchasers should examine stock if possible before receiving it.* Any good knife, good light and a careful operator will insure success. Samples of seed tubers sent to the Experiment Station will be examined without charge, reports made to the sender.

No. 312. March 28, 1910. OHIO PASTURES.

Ohio pastures with the woodland, which unfortunately is all more or less pastured, constitutes a portion of the State considerably in excess of the entire cultivated area. The pastures alone cover more than one-third of the entire area of the State. This might aptly be styled the "Neglected One-Third," because throughout the State far less care and attention are given to the maintenance and improvement of the pastures than to any other part of the farm enterprise. In the farm crop section of the State the permanent pasture is made up quite largely of the untillable part of the farm. The "plow" land is considered too valuable for pasture, and yet some data are at hand to show that a well managed pasture in the heart of the corn belt has yielded a net return per acre in excess of that received from corn. From some of the limestone hills of southeastern Ohio cattle that top the market at Pittsburg are finished on bluegrass. During the grazing season 400 lbs. gain per acre for cattle and 600 lbs. for sheep have been reported. If our pasture lands are capable of such returns as this, do they not deserve better treatment?

The Ohio Experiment Station wishes to secure weighing tests of gain per acre from all classes of livestock on pasture, and invites the cooperation of farmers generally in this connection. A little trouble in ascertaining the weights of stock as they go onto grass this spring will be of much interest at selling time. It may help us to put a proper valuation on the pasture land, and it may show the necessity of improving it. The care and management of the pasture—reseeding, cultivation, and fertilizing—are all farm problems in which the Experiment Station is ready to assist the farmer.

No. 313. June 13, 1910. THE BLADE BLIGHT OR YELLOWING OF OATS.

This disease is again prevalent. Its cause is definitely known to be due to a specific bacterium, and its progress is favored by cloudy, rainy weather. The disease begins as small, yellow centers on the blades or as long, marginal lesions occupying one or both edges of the leaf, sometimes yellowing the whole leaf and even extending down the sheath. Often the points of infection are so plentiful as to become confluent, causing a yellow, mottled appearance of the whole leaf. Short periods of sunshine cause the infested areas to turn quickly brown or red.

The amount of loss occasioned by this disease is exceptionally large during certain seasons. In 1907 many of the fields suffered a loss of one-half to two-thirds of the crop, producing oats weighing only 22 to 25 pounds to the bushel. This is explained by the impaired foliage.

Soils which are of high fertility certainly favor the oats and it may possibly pay to stimulate the oats crop with a light dressing of a mixture of one part nitrate of soda with two parts acid phosphate, although this has not been demonstrated. At any rate, the fertilizer will not be lost if the oats is followed by wheat.

As noted in Bulletin 210, of the Ohio Experiment Station, there is considerable difference in the resistance shown by the different varieties. This is again evident in 1910, on the oat variety plots at this Station. The variety "Wide-awake" is very susceptible, while the variety "Sixty Day" and its strains are quite resistant.

Bulletin 210, which treats of this disease, will be sent upon request.

No. 314. June 27, 1910. HOW TO FIGHT THE CHINCH BUG. By H. A. Gossard.

The Ohio Experiment Station sends to all who request it a small package of fungus culture which under favorable circumstances assists in controlling the chinch bug. It cannot be relied on, however, to be of much value in cool, dry weather, and other methods of control are more certain. Chinch bugs are now abundant in many wheat fields and will seriously injure adjacent corn fields as soon as the wheat ripens, unless preventive measures are adopted at the right time. As soon as the weather will permit, after the grain commences to ripen, plow up a strip of ground about ten feet wide around the infested fields, then disk and drag with brush bundles until the soil is pulverized into a fine dust. Now with a short log, from eight inches to one foot in diameter, or with a triangular trough made by nailing two boards together and then weighted with stone, make a furrow by dragging back and forth in the same track until a good ditch has been made across the line of chinch bug march. Where necessary, dress the sides of the furrow with a hoe, making sure that all slopes are even and dusty so that the bugs will be certain to slip back to the bottom of the furrow when they attempt to ascend. With a post-hole digger make holes every

12 to 15 feet in the bottom of the ditch to catch the bugs as they crawl along the bottom. When massed in the holes they may be destroyed by pouring kerosene or kerosene emulsion on them, or a block of wood may be sawed from a post of suitable size and a rod fastened into its center, this being used as a ram to crush the bugs in the holes. If necessary, use the post-hole digger to clean out the dead bugs and keep the holes in order. Owing to rains and use, the dusty sides of the furrow may become passable to the bugs, in which case it may be renewed by dragging the brush bundle through it again, or it may be better to make a new ditch parallel with the old. In case the new ditch is made, the old may be used for a coal tar barrier. The sides of the old furrow should be firmed with a hoe so dust particles will not rattle down on the tar. A slender line of tar should then be strung along the bottom of the furrow, or it may be poured along a line of hardened soil just outside the dust furrow. A water pot with a tubular spout is a good vessel for distributing the tar. The first line will soak into the ground, but soon forms a hardened crust, so that a second line, poured onto the first five or six hours later, will give good results. The tar should be renewed about twice per day during the migrating period of the insects, which usually lasts ten days or two weeks. Post-holes for traps may be dug along the inside of this strip of tar and bugs will be caught notwithstanding wet weather. Dr. Forbes, of the Illinois Station, estimates that a man or boy, giving all his time to guarding the barrier and keeping it in condition, can care for 80 to 150 rods of barrier. The tar will cost about 25 cents per day for a line 100 rods in length.

If by chance or neglect the bugs succeed in reaching the corn, spray the outside rows with kerosene emulsion before the insects spread over the field. Spraying with this material will cost less than \$1.00 per acre for ingredients.

Ohio Agricultural Experiment Station

CIRCULAR No. 96.

WOOSTER, OHIO, OCTOBER 1, 1909.



Section C, 5-year rotation, just before harvest.

PREFACE

The increasing interest which the farmers of Ohio are manifesting in field experiments, and the importance of so conducting such experiments as to obtain results which shall be useful and not misleading, are the reasons for the publication of this circular, which is, in the main, a reprint of a syllabus of an illustrated lecture, prepared a few years ago at the request of Prof. John Hamilton, Farmers' Institute Specialist of the Office of Experiment Stations, United States Department of Agriculture, for the use of Farmers' Institute lecturers. It is hoped that its suggestions may be found helpful to those who are entering upon this work.

CHAS. E. THORNE, Director.

ESSENTIALS OF SUCCESSFUL FIELD EXPERIMENTATION

By C. E. THORNE

INTRODUCTION

The experiment station is the distinguishing feature of the new agriculture. It stands for organized research in agriculture; for the concentration of the skill and energy of the entire State on the solution of the unsettled problems of the farm.

The experiment station is created to do things which are impossible to the ordinary farmer. It is furnished with costly equipment and conducted by men trained in the methods of scientific research, who are made free from other cares in order that they may devote their undivided energies to helping the farmer.

But while there are some things which can only be done by the aid of such an equipment as that of the experiment station, there are other things which the station can never do, and the farmer who profits most by the work of the experiment station is he who is himself an experimenter.

It is the province of the experiment station to discover and formulate general principles. The application of these principles must be made by the farmer himself. Even were there an experiment station in every county, there would still be hundreds of farms within each county on which some of the conditions would vary from those of the station, and while no farmer should attempt to duplicate the elaborate work of the experiment station, neither can any farmer afford to blindly accept the conclusions reached at the experiment station without subjecting some of them to the test of further investigation on his own farm.

Were there no other reason for this than the benumbing effect upon the intellect produced by the unthinking acceptance of the dicta of others, as evidenced by the unnumbered centuries during which the sickle remained unchangingly a chief implement of husbandry, this unchangeableness symbolizing a similar monotony in the farmer's intellectual processes, that alone would be abundantly sufficient. The farmer of today must learn to think or he is lost, and nothing is more conducive to exact thinking than scientific experiment.

The experiment station should carry its work far enough to demonstrate clearly the lines which practical application must follow, but after it has reached its uttermost limit there will still be much for the farmer to do.

Many experiments which farmers attempt, however, are either valueless or actually misleading, because of failure to observe some of the essential conditions of successful experimentation, for investigation in agriculture by experiment is a business by itself, entirely distinct from ordinary farming, and many a good farmer will overlook points of vital importance to the success of an experiment until his attention is called to them. It is in the hope of encouraging farmers to experiment more largely and to assist them in making their experimental work more effective that the following suggestions are offered.

SELECTION OF SOIL

A matter of first importance in preparation for field experiment is that the soil shall be as nearly uniform as possible in character. To secure such uniformity the following points should be considered:

GEOLOGICAL HISTORY

It is important, in experiments with fertilizers especially, to know whether a soil is of sedentary, drift, or alluvial origin; that is, whether it has been formed by the natural weathering of the underlying rock; by the action of the great glaciers, which once overspread the northern portion of the United States, grinding up the rocks over which they passed and rearranging their particles in the moraines and sheets of drift which they left behind them as they retreated northward, or by the action of flood waters of rivers and streams, washing down the soil from the higher lands and depositing it in the alluvial flood plains or "bottom lands" of the streams—a force which is in active operation today—as this knowledge may throw considerable light upon different methods of treatment.

A sedentary soil is liable to be more uniform than a drift or alluvium, because in the case of transported soils there is generally a more or less uneven deposit of materials, an excess of gravel and coarse sand appearing in one spot and of silt and finer particles in another. A heavy sheet of drift may sometimes become weathered into practically the same condition as a sedentary soil, while it would seem that some of the great loess deposits would offer especially good conditions to the field experimenter, the loess being the fine-grained, silty soils found in some of the Western States, and whose origin is apparently due to the blowing of the dry surface dust into banks and hillocks, sometimes many feet in depth.

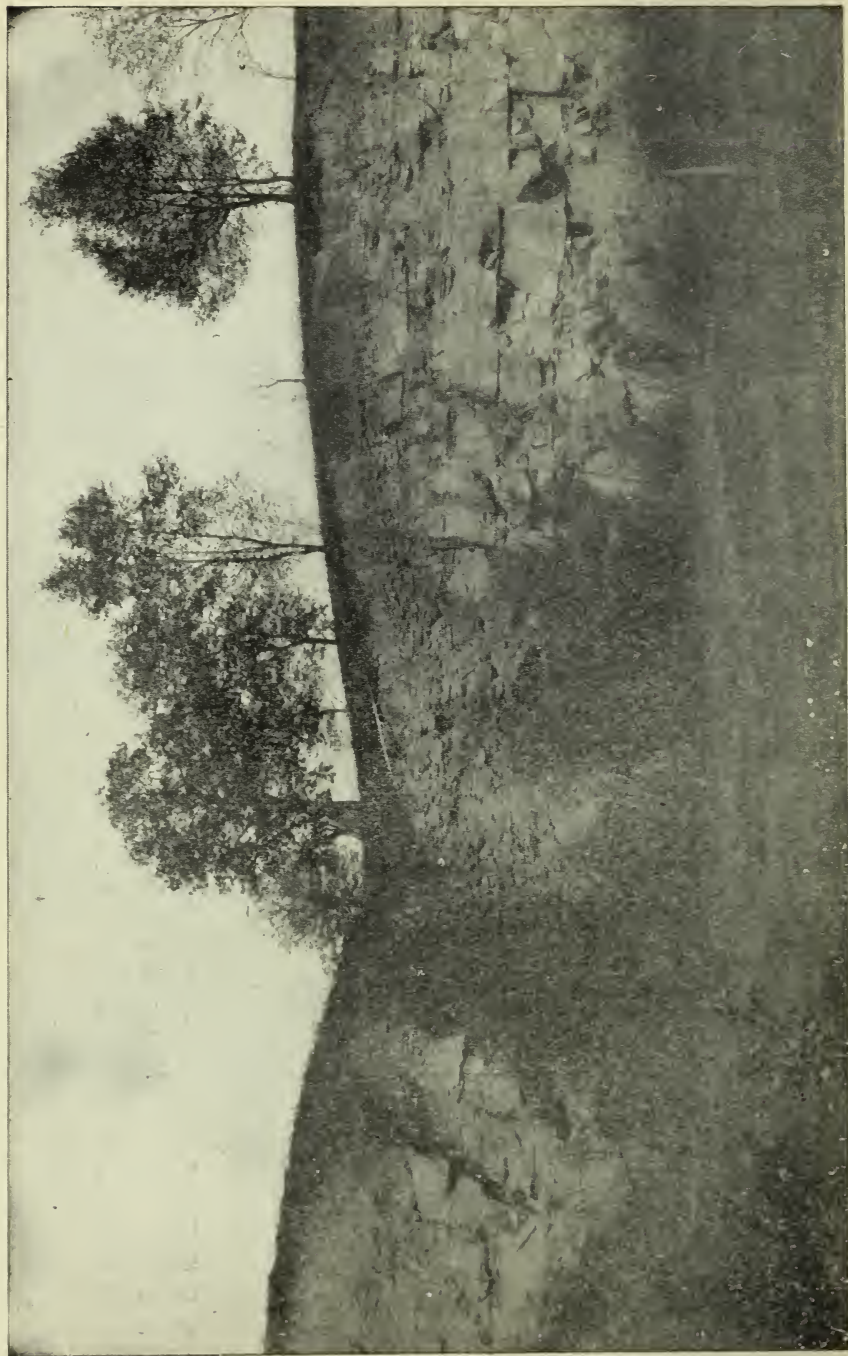


Fig. 1. Face of a stone quarry in a glaciated district, showing the heavy layers at the bottom, gradually breaking up into thinner layers toward the surface and finally ending in a finely broken stratum, over which is spread the thin drift sheet, with its contained pebbles and small boulders. In many places in this region this drift sheet is replaced by a thin soil filled with the angular fragments of the underlying rock—such a soil as would be made by a little further disintegration of the upper stratum of rock shown in the picture.

PREVIOUS MANAGEMENT

It is also important to know something of the previous management of the soil. The great Rothamsted experiments have shown the persistence of the effect of applications of barnyard manure—the yield from a formerly manured plot remaining more than double that of the unmanured land alongside for thirty years after the manuring had been discontinued. Other illustrations are given to show the effect of leaving fence rows or lanes uncultivated for a period of years and then bringing them into comparison with lands brought under cultivation at an earlier date. Again, a tree which has stood for years after the remainder of the forest has been cleared away, and whose shade has been a resting place for live stock, may cause a considerable variation in the productiveness of the soil which will be manifest long after it shall have been cut away. These points are clearly shown in Figures 2 and 3.



Fig. 2 Showing the growth of corn on an old roadside fencerow, in a region where the discovery has recently been made that it is cheaper to fence cattle in than to fence them out, and consequently the fences are being limited to such as are necessary to inclose permanent pastures, and many miles of road are entirely unfenced.

TOPOGRAPHY

Absolutely level land is seldom adapted to field experiment, for the reason that no land is so flat that it does not have slight inequalities of surface and on such land the minor depressions receive a larger share of the rainfall by surface drainage from the higher portions, and thus have an advantage in dry seasons when water may be the controlling factor in producing increase of crop, while they may be at a disadvantage in seasons of excessive rainfall. When

the subsoil is porous these depressions may merely be a little more fertile than the higher portions through increased accumulation of humus, but if the subsoil be impervious to water it may give rise to a semiaquatic growth of vegetation which may radically modify the behavior of the soil under cropping. On the other hand, steep hill-sides are not adapted to experiment, because the water from heavy rainfalls in washing over them will cut them into gullies or transport fertilizing materials from plot to plot.

The ideal topography for field experiment is a broad, gentle slope of about 1 to 2 percent, or just enough to permit the surplus water of heavy rains and melting snows to flow off uniformly and completely.

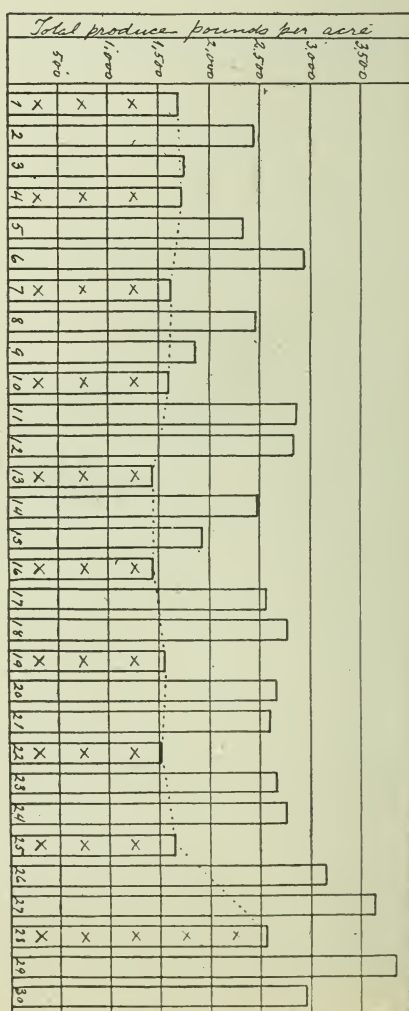


Fig. 3. Diagram showing the yield of the unfertilized plots in an experiment in which corn, oats, wheat, clover and timothy have been grown in a 5-year rotation for ten years. There are thirty plots in the series, and every third plot, beginning with No. 1, has been left continuously unfertilized. The average yield of these plots ranges between 1,400 and 1,750 pounds per acre until No. 28 is reached, when it suddenly mounts to 2600 pounds. This experiment was located in a field which had been in cultivation for fifty years or more, and at the time it was laid out in plots no difference was apparent between the land occupied by Plot 28 and other portions of the field, but it was afterwards learned that this plot and parts of the adjacent plots had been occupied by a lane until some seven years before the test began.

ROTHAMSTED EXPERIMENTS, HOOS FIELD

Barley 51 years in succession on the same land.

Produce, without manure and with farmyard manure.

	Bushels per acre	
	First 20 years, 1852-71	51st season, 1902
Unmanured every year.....	19.9	12.7
Manured every year first 20 years, last 31 years no manure.	48.2	27.5

ARRANGEMENT OF PLOTS

SIZE OF PLOTS

Farmers generally have the idea that experiment plots should be made as large as possible, an idea, naturally following their observation of the inequalities of most soils; but the practical difficulty in the way of using large plots is the fact that for a comparative experiment the soil must be as nearly absolutely uniform as possible, and it is extremely difficult to find large areas having sufficient uniformity. In almost all cases it will be found better to use a large number of small plots than a small number of large plots, since by multiplying the plots the variations of the soil can be more evenly distributed. A field of ten acres, for example, in which it is desired to make ten comparisons, will yield results of far greater value if cut into 100 plots containing one-tenth acre each, giving ten plots, distributed over the field, to each particular comparison, than if only ten plots are employed.

The most convenient size of plots for computation is one-tenth acre. When the plots are reduced much below one-tenth acre in size another element enters into the problem, namely, the individuality of the plant. One-tenth acre of corn, as usually planted, will contain nearly a thousand plants, and this number might be grown from a single seed ear; but experiments have shown that ears taken from the same variety and grown on neighboring stalks may vary 50 percent in their produce. Hence, even for plots of one-tenth acre, the greatest care should be taken to secure seed which has been drawn from a considerable number of ears and thoroughly mixed. In the case of wheat or oats a tenth-acre plot may contain from 100,000 to 150,000 plants, the seed of which has probably been obtained from 3,000 to 5,000 heads of grain, representing several hundred separate plants. Hence, we may safely use a smaller plot for the small grains than for corn.

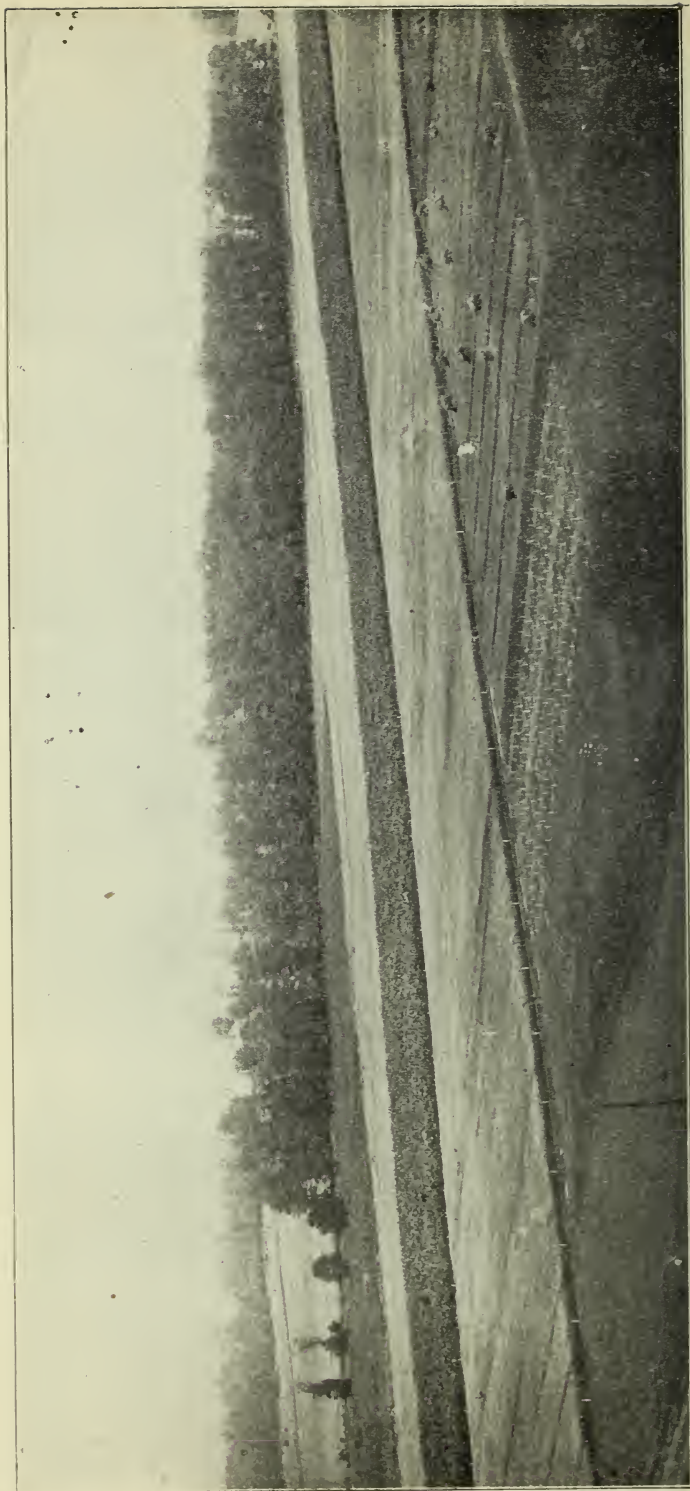


Fig. 4. Part of a field of about sixty acres which is wholly devoted to plot experiments. It slopes gradually toward the north with secondary slopes east and west, which give sufficient fall for the lateral tile drains that are laid between the plots, running east and west and emptying into mains which run north, one on each side of the field.

SHAPE OF PLOTS

It is generally conceded that experiment plots should be long and narrow, both for greater convenience of cultivation and also because this shape permits a better arrangement with respect to irregularities of soil. The minor inequalities of the soil are usually caused by the gradual washing of the surface into small ridges and valleys, which can be so crossed by a long and narrow plot as to cover equal portions of the lower and higher land, whereas this would not be so readily accomplished in square plots. It is well to adapt the width of the plot to that of the machinery in use. A plot 16 feet wide, for example, will contain four rows of corn four feet apart, or five rows of potatoes 38 inches apart. It may be sown with three "throughs" of an 8 hoe, 8-inch drill, and cut in three swaths with a machine having a 5½ or 6-foot cutter bar. The width of the plots should be adjusted to the drainage. When they are more than 16 feet wide it will be necessary on most soils to give each plot a separate drain.

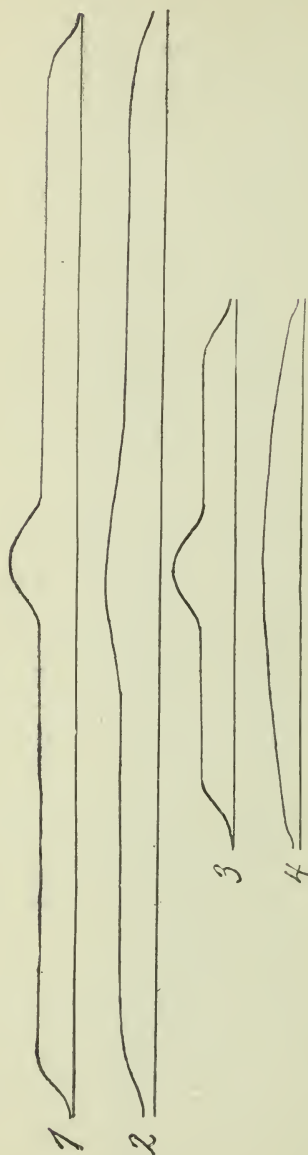
SURFACE DRAINAGE

Whatever the natural topography may be, under most circumstances the uniform disposal of excess of surface water may be facilitated by a slight ridging of the plots, which may be accomplished by plowing the plots separately. To attain this end successfully the plots should be comparatively narrow, in order that the cross harrowing may so distribute the ridge left by the plow as to leave a gradual slope from the middle of the plot to the sides. On wide plots there will always be a flat space left between the ridge and the furrow.

It is not necessary nor advisable to repeat the ridging at every plowing. On the contrary, the effect of ridging will remain apparent for five to ten years, even though subsequent plowings and cultivations be, as they should be whenever practicable, across the plots.

CROSS DRAINAGE

One of the chief objects in separating the plots by dead furrows is to prevent cross drainage of surplus rainfall. Where there are no surface drains such water will, of course, follow the natural slopes of the land, and these are practically never sufficiently regular for the purpose of plot experiment. In variety testing and cultural work this may not always be a matter of great importance, but in fertilizer tests it is essential that the fertilizer applied to each plot be confined to that plot, which can not be the case if the surface water is permitted to flow indiscriminately across the plots.



EFFECT OF RIDGING ON WIDE AND NARROW PLOTS.

Fig. 5. No. 1 shows a plot two rods in width as first plowed, and No. 2 shows the same plot after the harrow has gone over it, partly leveling the ridge or back furrow. Nos. 3 and 4 show a plot one rod wide under similar conditions. It will be observed that in the narrower plot the effect of cross harrowing is to leave a surface having a gradual slope from the crest to the furrow, whereas on the wide plot there will be a flat space left between the two. The practical difference between the two methods of plowing is that the surplus water of heavy rains and melting snows will flow off the narrow plot more uniformly and with less washing and gullying than off the wider one.

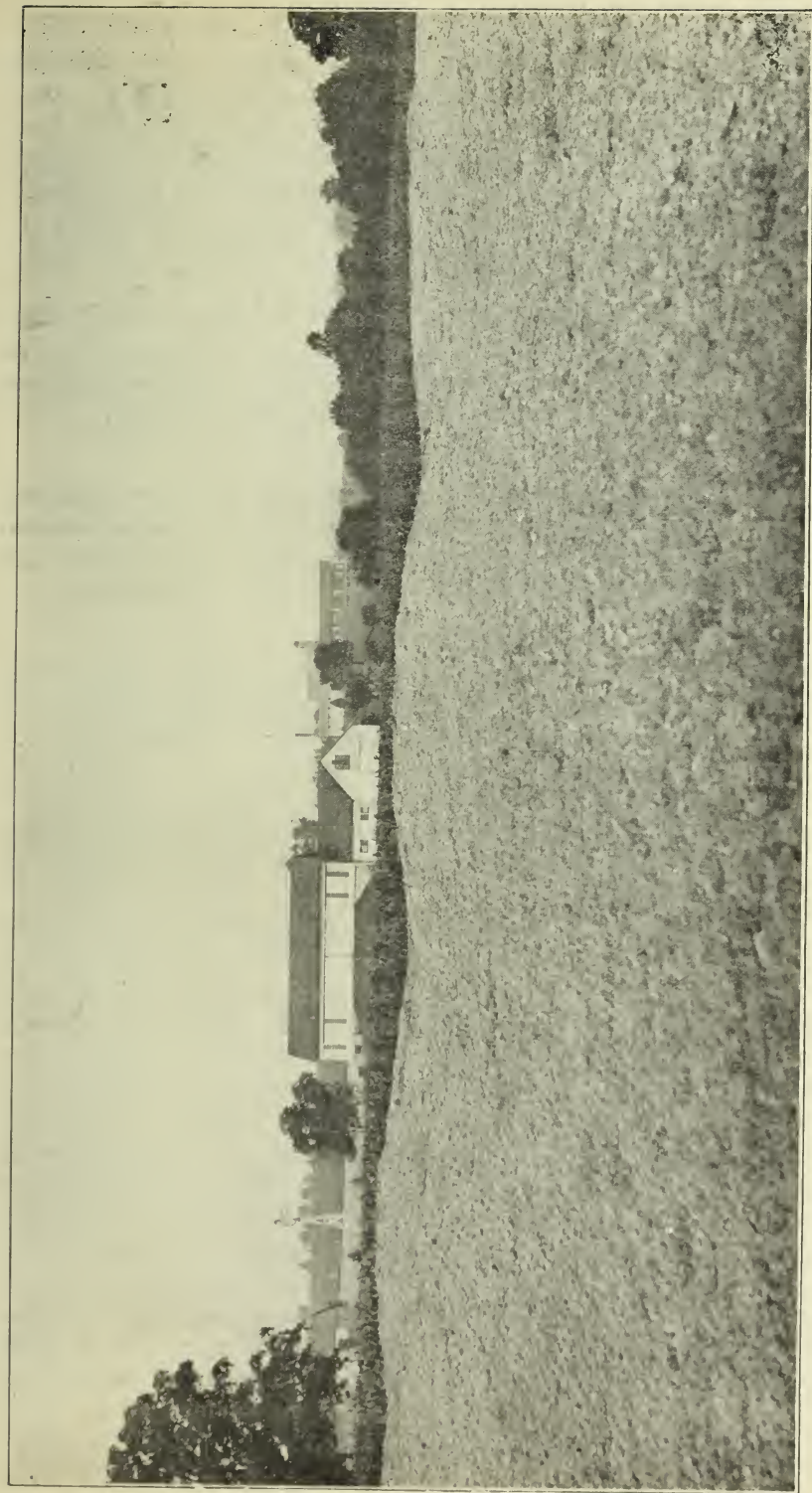


Fig. 6. Contour of plots 18 feet wide from center of furrow as obtained in actual practice. These plots have just been ridged for the third time in twelve years. Future crosswise plowing will materially reduce the height of the ridges.

Even in such work as variety testing, however, it is desirable that the surface water find its way off the plot as quickly as possible. If it stands in minor depressions over the plot it will cause irregularities in yield; if the plots are laid off up and down a slope the water will follow down the drill rows, washing out many plants during the spring thaw, while if the plots are laid off across the slopes there will be cross washing which, in fertilizer comparisons, will vitiate the results. The best arrangement in such work is to so ridge the plots that the surface water will flow from the middle down the sides of the plots into dividing furrows, these being so graded as to carry it away. Some gullying of the furrows is almost unavoidable, but it is better there than within the plot itself.

CROSS FEEDING

Another prime object of a furrow between the plots is to prevent cross feeding—that is, the extension of the roots from an unfertilized plot, for instance, to one that has been fertilized—and this is practically accomplished by the ordinary dead furrow.

UNDERDRAINAGE

Provision for the removal of an excess of soil water is absolutely essential to successful field experiment. Such excess may be naturally removed by stratified rocks lying at shallow depths below the surface, or in rare instances deposits of gravel may be found sufficiently uniform to serve this purpose, but in the vast majority of cases, especially with soils that have been so long in cultivation that a hardpan has been formed, it will be necessary to aid nature by artificial drainage.

In draining for plot experiment the drains should be so located as to give uniform drainage to each plot. When the plots do not exceed a rod in width and the soil is reasonably porous, a single drain may serve two plots, being located under the division space between them, but in the majority of cases it would be better to give each plot its separate drain, located either under the dividing space or under the middle of the plot. The former location is probably the better one where it is not designed to study the composition of the drainage waters, as the surface waters accumulating in the furrow will be more promptly removed if the drain lies immediately beneath the furrow than if it lies under the middle of the plot.

Figure I presents a good illustration of conditions for natural underdrainage. As stated in the description of the cut, there is a gradual transition from the heavy layers of stratified rock, through the lighter layers and broken strata to the thin sheet of soil, which has been formed by the slow weathering of the surface rock, aided

by the action of ancient glaciers. On this soil trees are growing which send their roots through to the rocks below. When the trees are cut away their decaying roots furnish natural drainage channels to the rock seams below, but these channels are gradually obliterated by the scraping of the plow and the trampling of the teams and grazing stock. Eventually the subsurface becomes so compact as to greatly retard the percolation of the surface water, and artificial drainage becomes necessary.

DIVISION SPACES

Division spaces two feet in width have been found sufficient for the separation of the plots, even in fertilizer tests, provided the land is plowed in ridges with the dead furrows falling at the division spaces. Such narrow spaces necessitate special care in seeding in order that the grain may not be sown too far down in the furrow. The dead furrow is rightly named, and in proportion as the seed falls within its influence will the growth of the plant be diminished. When the division space is not more than two feet wide and the planting is accurately done, the resulting produce will probably be a more accurate index of what might be expected under ordinary field culture, under the same treatment, than where the spaces are wider, as in the latter case the outside rows will have a larger area for root extension, before reaching the dead furrow, than in the former.

OLD RIDGES AND DEAD FURROWS

It is of prime importance to so arrange the plots as to avoid the errors arising from old ridges and dead furrows, for either a ridge or a furrow, running lengthwise in a plot, may completely reverse the results of the test. Wherever possible, experiment plots should be laid out across the direction in which the field has previously been plowed.

CHECK PLOTS

A matter of great importance, too often lost sight of in field experiments, is the repetition of check plots. In the most uniform soils there will be some variation in the produce of adjoining plots from season to season. Even were the actual plant food the same, the variations in level which occur on all soils will produce an unequal distribution of moisture, and moisture may often be a more important factor in determining crop yield than plant food. The ideal system of plot experiment would leave every alternate plot as a check. Next to this comes the plan of leaving every third plot as a check, thus having a check plot on one side or the other of every plot under treatment. In fertilizer tests the check plots may be unfertilized or subjected to uniform dressings with a standard fertilizer or manure, depending upon the object of the experiment. In variety tests the check plot should be planted to a standard variety. The importance of repetition of check plots will be further illustrated under the head of calculating increase.



Fig. 7. Two feet wide dividing space between plots of corn.

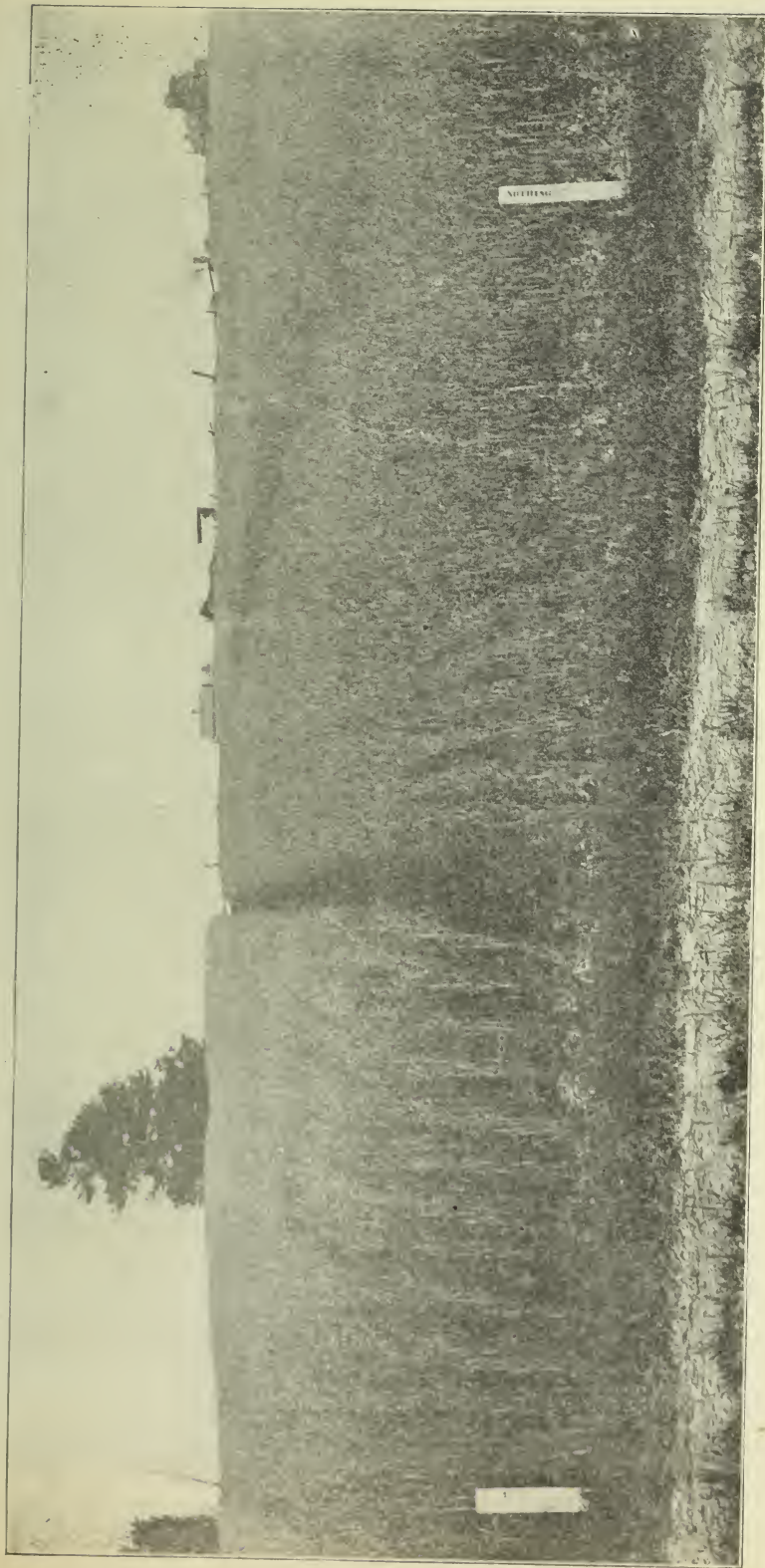


FIG. 8. Two-foot wide dividing space between plots of oats.

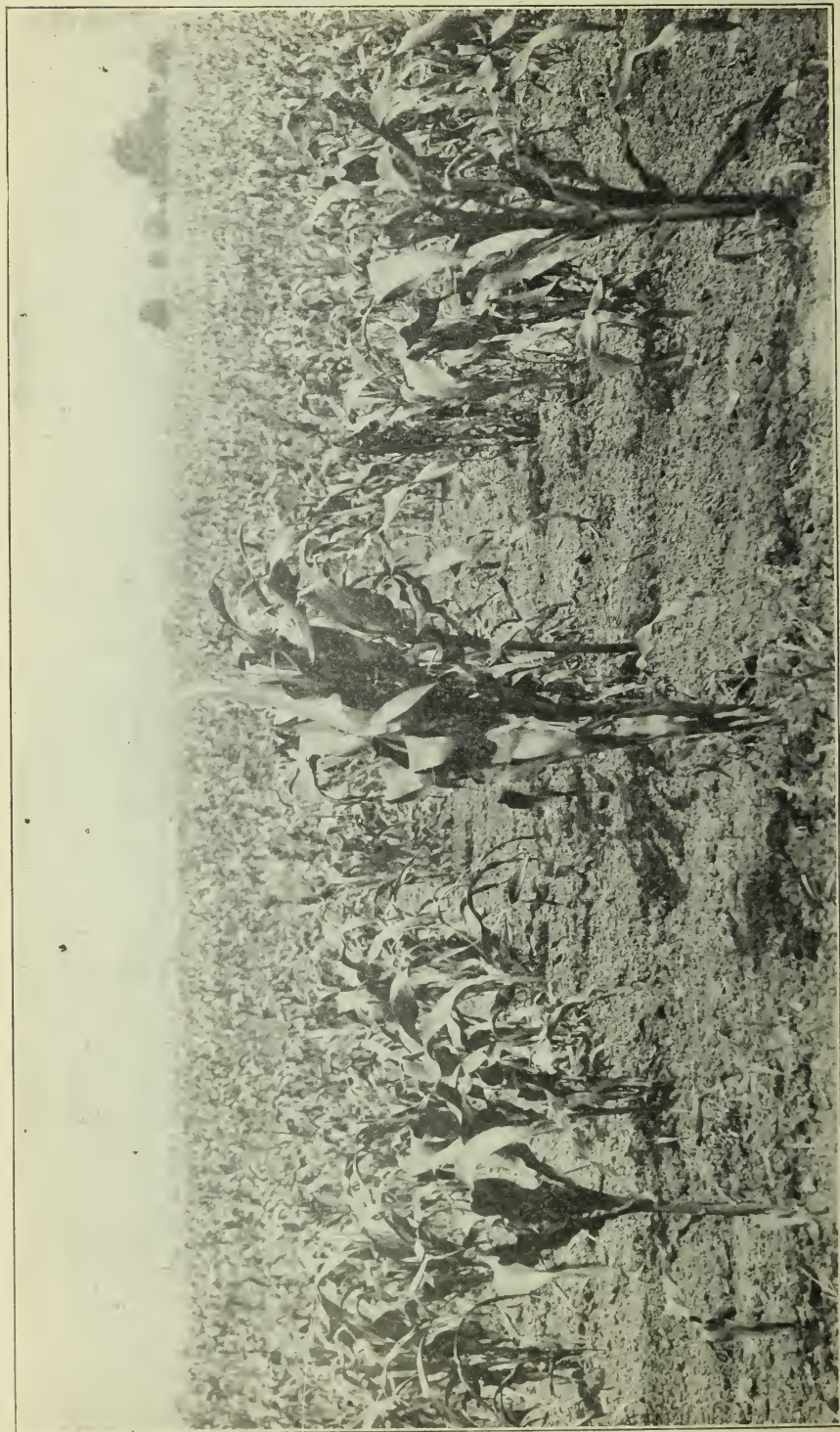


Fig. 9. The middle row of corn in the picture is located on the ridge or back furrow formed by throwing two furrows together. It will be seen that if one plot has such a back furrow and others do not, the apparent results of a comparative test may be very misleading. The effect of an old dead furrow may be equally as fatal to accuracy in results

PERMANENT BOUNDARIES

A plot of land designed for experiment should be definitely marked with permanent stakes, especially if tests with fertilizers are to be made. A very convenient marking stake for such purposes is a piece of second-hand gas pipe, about two feet long, driven to such a depth that harvesting machinery will pass over it. A block of, say, ten plots may be marked with such stakes, set at the corner of the block, the intervening distances to be measured for each planting.

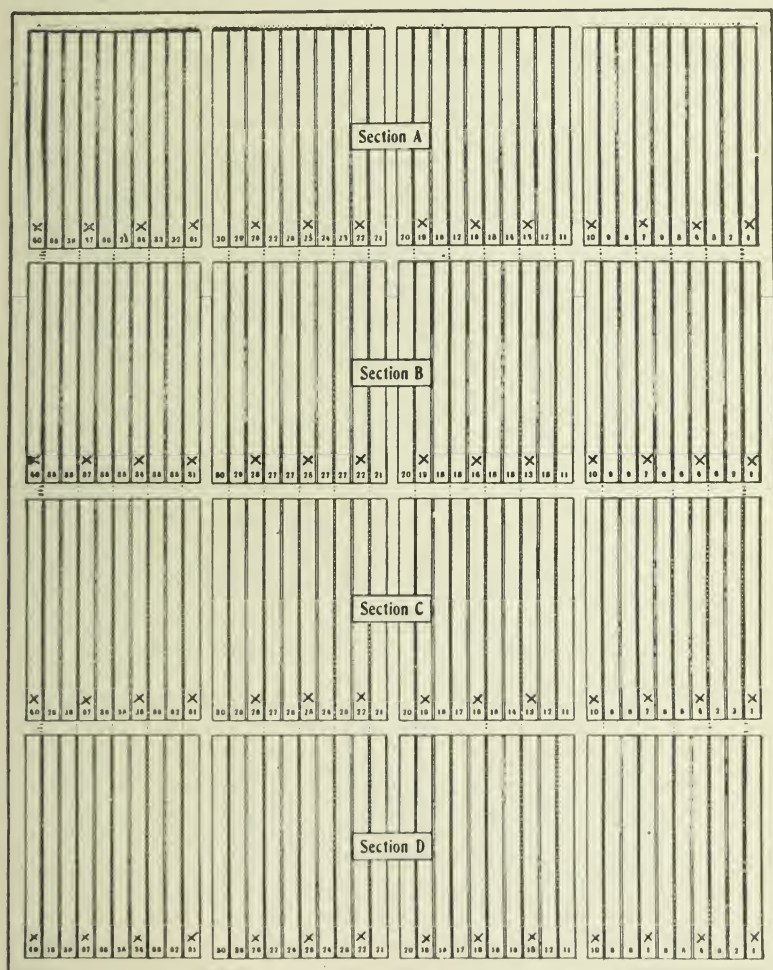


Fig. 10. Four ranges or tiers of plots, 40 plots each, as actually employed in an experiment in which corn, oats, wheat and clover are grown in rotation, each crop being grown each year. The plots marked X are check plots.

HEADLANDS AND ROADWAYS

Ample headlands should be left across the ends of every block of experiment plots. Not only are these headlands needed to prevent the breaking down, in turning while cultivating, of such crops as corn or potatoes, but they are required in the harvesting of the small grains, in order that the machine may be driven around the plots empty, and they are even more urgently needed in plowing, as the trampling of the soil by the team in turning the plow will materially affect the yield of the following crop. These headlands may be made 18 feet wide, but 20 feet is better.

In addition to the headlands there should be roadways at intervals through every large group of plots, to permit the first passage of the machine in harvesting, or the continual passing where it is necessary to cut the grain but one way, and the passage of wagons in hauling manure or grain. An experiment plot should never be used as a roadway, for the reason given above, that the additional trampling and packing by the teams and wheels, even in the driest weather, will so change the physical condition of the soil as to affect the future yield of crops. A convenient arrangement, where the plots are not more than 16 feet wide, is to leave a 12-foot roadway between blocks of eight or ten plots. These roadways may be planted to the same crop as that grown on the plots, the roadway to be cut out and the produce set to one side where it will not be mixed with that of the plots before the harvesting of the plots is begun.

The headlands, however, should be kept in grass, in order that the plots may at all times be accessible. Nothing will add so much to the interest in and value of an experiment as to be able to visit it at any time and to see clearly the contrast between plots. It is not waste, but economy, to give a little land to this purpose.

LABEL STAKES

Every plot should be distinctly marked with a label stake, giving the number of the plot and an indication of its treatment. A very convenient stake for this purpose is a board four inches wide and 30 inches long, sharpened at one end, painted with three coats of white-lead paint, and lettered with price markers or with brush. Such stakes, if taken up and sheltered through the winter, will last ten years or more.

FIELD EXPERIMENTATION

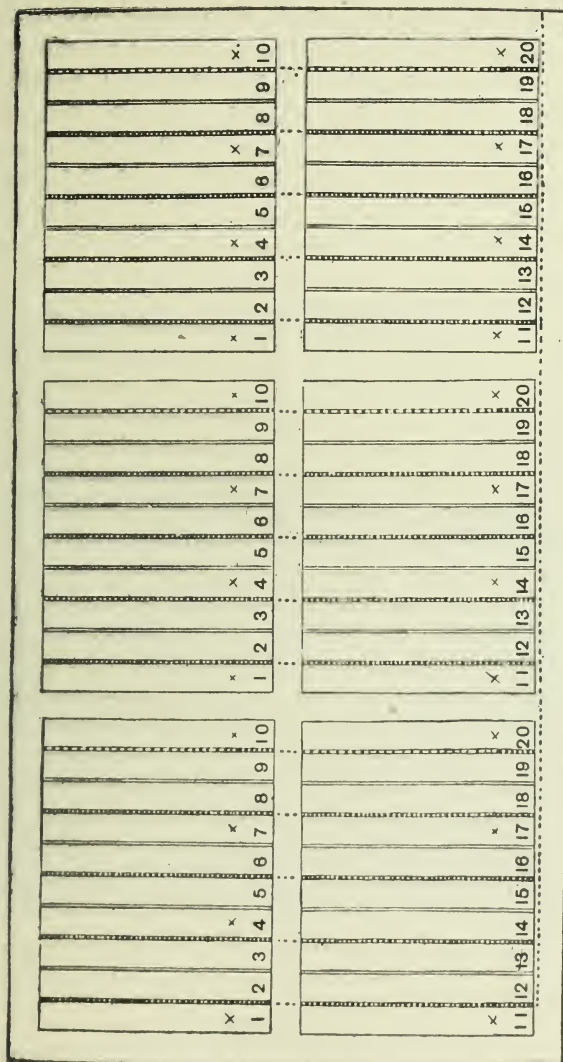


Fig. 11. Six blocks of ten plots each, arranged for a 3-year rotation.

PREPARATION OF LAND FOR CROPS

UNIFORM PLOWING

It is highly important that the plowing and fitting of the land for a comparative experiment be as uniform as possible in every respect. A difference of a few weeks in date of plowing may cause as great a difference in yield of crop as will be produced by difference in fertilizing, and far greater than is usually observed between varieties. For this reason the plowing should, as a rule, be done across the plots, and when it becomes necessary to plow the plots separately, in order to ridge them, the work should be pushed forward as expeditiously as possible. On this account it is well to have the plots arranged in blocks of ten, planning the test so that each block will have its complete series of checks, independently of the others.

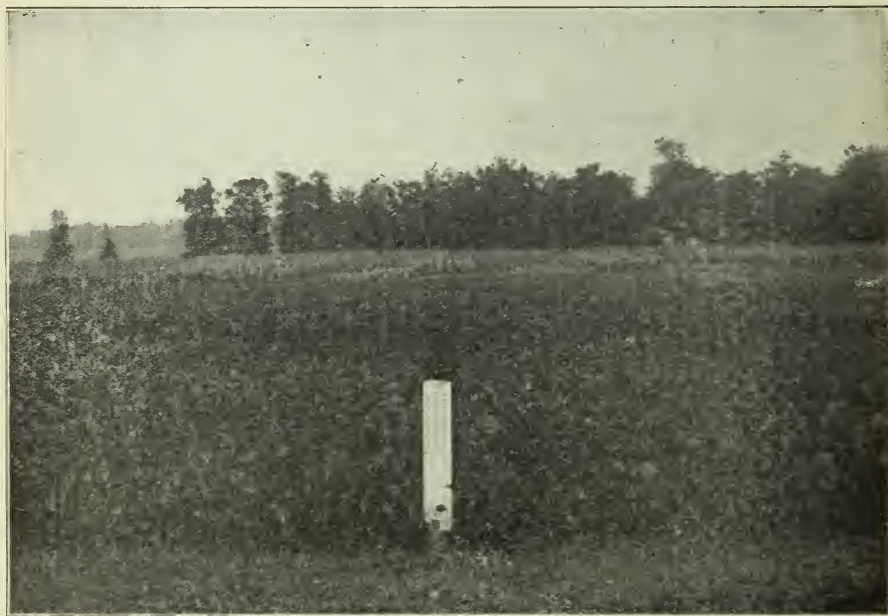


Fig. 12. A convenient label stake four inches wide by 30 inches long, painted white and lettered with a brush. These label stakes are useful but should never be permitted to take the place of a carefully written record or diagram, as stakes may be easily transposed or lost. The stake should be so lettered as to show the number of the plot at which it stands, and also the kind and amounts of fertilizer applied to that plot.

MANURING AND FERTILIZING

Both manures and fertilizers may be distributed by machinery more uniformly and accurately than by hand. In a comparative test of manures or fertilizers it is important that the material be kept entirely on the plot, leaving the dividing spaces entirely untouched; but where the test is one of varieties or methods of culture the

entire surface may be covered. In applying fertilizers it is a good plan to bring the applications intended for the different plots all to the same bulk, by mixing them with dry sand, so that a single setting of the drill may suffice for the entire experiment. Even then it will not always be possible to exactly gauge the material, for mixtures which are largely made up of such salts as nitrate of soda and muriate of potash will pass through the drill less readily than those which contain a larger proportion of sand. It is a good plan to test the drill by sowing an equal bulk of material on a plot not designed for experiment before beginning the actual work. The fertilizer will run more slowly as the drill becomes nearly empty; hence it is well to set the drill so that a little will be left in it after the plot has been gone over, and then turn back over the work until all is out.

Machines are now made for distributing fertilizers and lime broadcast. They are made wider than the ordinary fertilizer drill and are guaranteed to spread even slaked lime satisfactorily. Where such a machine is not available, the manure spreader may be used for lime spreading, first spreading a layer of chaff or similar material in the bottom of the machine and spreading the lime on this. Where small quantities of lime are to be applied—1,000 pounds or less per acre—it will be an advantage to gear the machine so that the apron will travel more slowly than in ordinary work. The best manure spreaders are now fitted with hoods and slow gearing for lime spreading.

MACHINES SHOULD BE ACCURATE

While a good machine will do better work than can be done by hand, there are many machines in use which are not fit for experimental work. There are both corn planters and grain drills which do not distribute the grain uniformly, while there are others which are unsuited to the experimenter's purpose because they are too difficult to clean out, thus greatly increasing the difficulty of making variety tests. In thrashing, this last difficulty is still more conspicuous. The modern thrashing machine is gotten up at a low cost and intended only for rapid work on a large scale, and is altogether unsuited to the separation of different varieties of grain. The older thrashing machines, with the traveling apron, are better adapted to this work than the modern machine. There should be no place for grains to lodge in passing through the machine, but it should be so constructed that every grain entering the cylinder will be promptly carried through the machine and out at the proper place. It is possible to do this, but of course the cost of the machine will be increased.

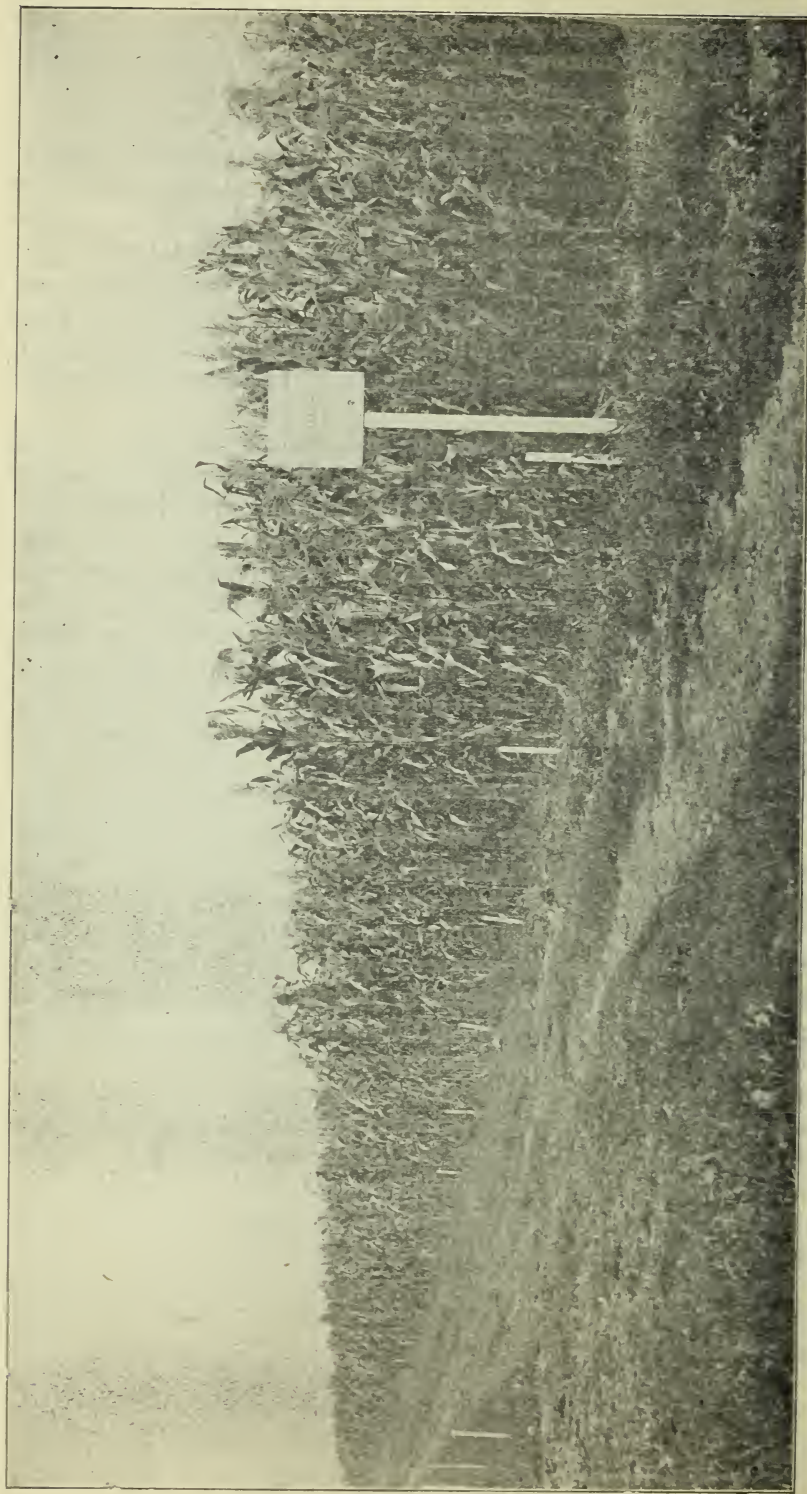


Fig. 13. Showing a sign board for the convenience of visitors. This sign board should show the nature of the experiment by indicating the length of the rotation and the kind of crops grown, etc.



Fig. 14. Distributing lime with a lime spreader This implement is much to be preferred where lime is used in any considerable quantity.

SELECTION OF SEED

The selection of seed is a very important matter in field experimentation. Defective seed means an imperfect stand, and an imperfect stand means an unreliable experiment, for no method of calculation yet known will correct the inequalities of an irregular stand. Not only should the seed be strong in vitality, but it should be uniform in size, because such uniformity not only is necessary to uniformity in distribution by machinery but also to uniformity in growth of the young plants. For this reason the seed corn should be selected from the middle of the ear, rejecting the butts and tips, and wheat and oats and other small grains should be carefully graded by passing them through a fanning mill and over a sieve, which will take out the small and imperfect grains.

THE ROWS SHOULD BE STRAIGHT

That rows should be straight applies even more forcibly to the small grains than to corn, for a careless driver who allows his rows to run together by so much reduces the yield of the plot, as experiments have shown that where the quantity of seed passes above a certain maximum—and the regular seeding should be near this maximum—then the yield falls off; so that when two rows run together not only do we lose all the produce of one of the rows but part of that of the other.



Fig. 15. Distributing lime with a manure spreader. This is the best substitute for the special lime drill which we have. By spreading litter of some sort over the apron and putting the lime on this, and by using the hood, as shown in the cut, we can get a fairly satisfactory application of the lime, although the work will be found to be much more dusty and tedious than with the special lime spreader.

THE ENTIRE PLOT SHOULD BE PLANTED

In drilling the small grains most drills will travel a short distance before the seed reaches the ground. If the drill is started at the exact end of the plot, therefore, there will be a short space unsown. To guard against this the drilling should extend beyond the ends of the plots, the excess being cut away before the plot itself is harvested. The best way to accomplish this is to stretch a line between the stakes marking the corners of a block of plots, and with a hoe cut out a narrow strip under the line. The nose of a machine may then be made to follow this strip, thus quickly cutting away the excess, which of course must be kept out of reach of those who haul in the grain, if the trimming has been left until harvest time, but the better way is to trim the plot ends while the crop is still green, making hay of the produce. Not only will this method remove all danger of mixing the results, but it will add to the satisfaction of watching the maturing of the different plots.

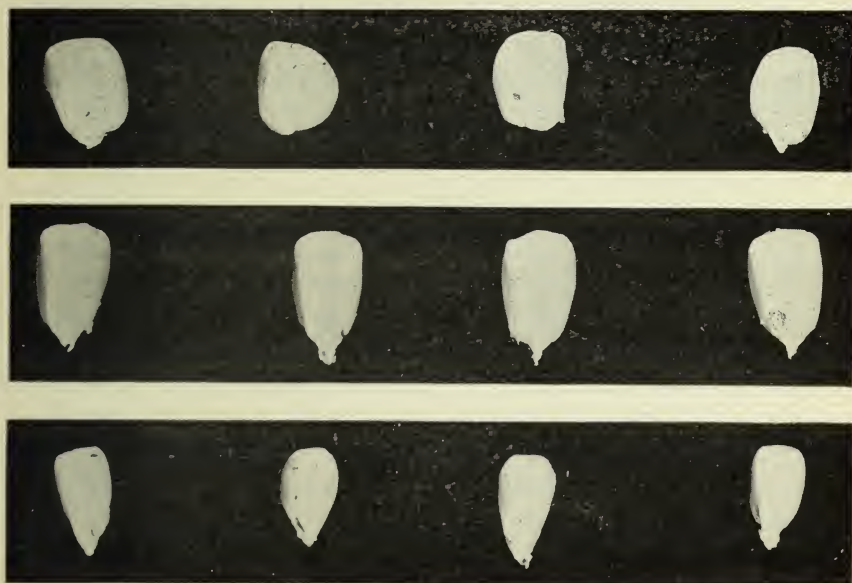


Fig. 16. Four grains of corn each from butt, middle and tip of the same ear, showing difference in size.

PLANTING AND CULTIVATION

MACHINE WORK PREFERABLE

Wherever possible machinery should be used in planting and cultivating. There is no longer any question as to the superiority of drilling the small grains over sowing them broadcast, and the

same principles apply to the corn planter, at least, if not to the potato planter. Certainly they do to the tobacco planter. The seed grain is deposited more uniformly by the drill or planter, whether as to quantity of seed, depth of planting, or uniformity of covering, than can be done by hand. Even the hand corn planter is better than dropping the seed by hand and covering with the hoe, while a man and two boys will set tobacco or cabbage plants not only very much more rapidly but also much better with the machine on which they all ride, carrying with them a barrel of water which automatically deposits a cupful at uniform distances in the row, the boys alternately placing a plant in the freshly opened furrow just as the water reaches it, while the machine closes the furrow and presses the earth around the plant.

In cultivating, and especially in harvesting, machinery is essential to rapid work. An experiment with cereals is incomplete unless the proportion of straw or stover to grain is determined, and it is practically impossible to secure uniformity of stubble, either of small grains or corn, by hand cutting.

In thrashing the small grains no one would now think of using the flail where it was desired to make an accurate determination of the separate product of straw and grain. With corn, however, thrashing machinery has not yet reached a stage at which it can successfully compete with hand husking.

HARVESTING

CUTTING GRASS PLOTS

In experiments with crops grown in rotation the grass and clover crops usually occupy the dividing spaces, as well as the plots proper. A convenient and fairly accurate method of harvesting such plots is to drive the machine to stakes, so set that the point of the machine will just reach the outside of the plot. A careful driver with a steady team can thus cut a swath as straight as though a line had been stretched. After the outsides are thus cut, the cutting out of the middle is a simple matter. The dividing spaces should be left uncut until the hay has been taken up from the plots.

HARVESTING SMALL GRAINS

When plots of small grain are arranged in blocks, as has been above recommended, the roadways are first cut out, the ends of the plots straightened, if this has not been previously done, after which, if the grain be not lodged, the machine may cut up one side of the block and down the other, running empty across the ends, of course, but a man should follow the machine to remove the residue that may be left on it as it leaves the plot and to see that each sheaf is finally left on the plot to which it belongs.

HARVESTING CORN

The corn harvester will no doubt come into general use because of its great saving in labor and because of its uniform stubbles, but in experiment work it is indispensable that a gleaner should closely follow the harvester in order to pick up dropped stalks and ears which may be broken off and keep them on their proper plots.

HARVESTING POTATOES

Potatoes may be harvested with the potato digger with a fair degree of accuracy by harrowing the ground after all the potatoes thrown out by the digger have been taken care of, and picking up those exposed by the harrow. The advantage of machine over hand work, however, is much less decided in handling the potato crop, whether in planting or harvesting, than in case of grain and grass crops.

WEIGHING

THE WAGON AND STOCK SCALE

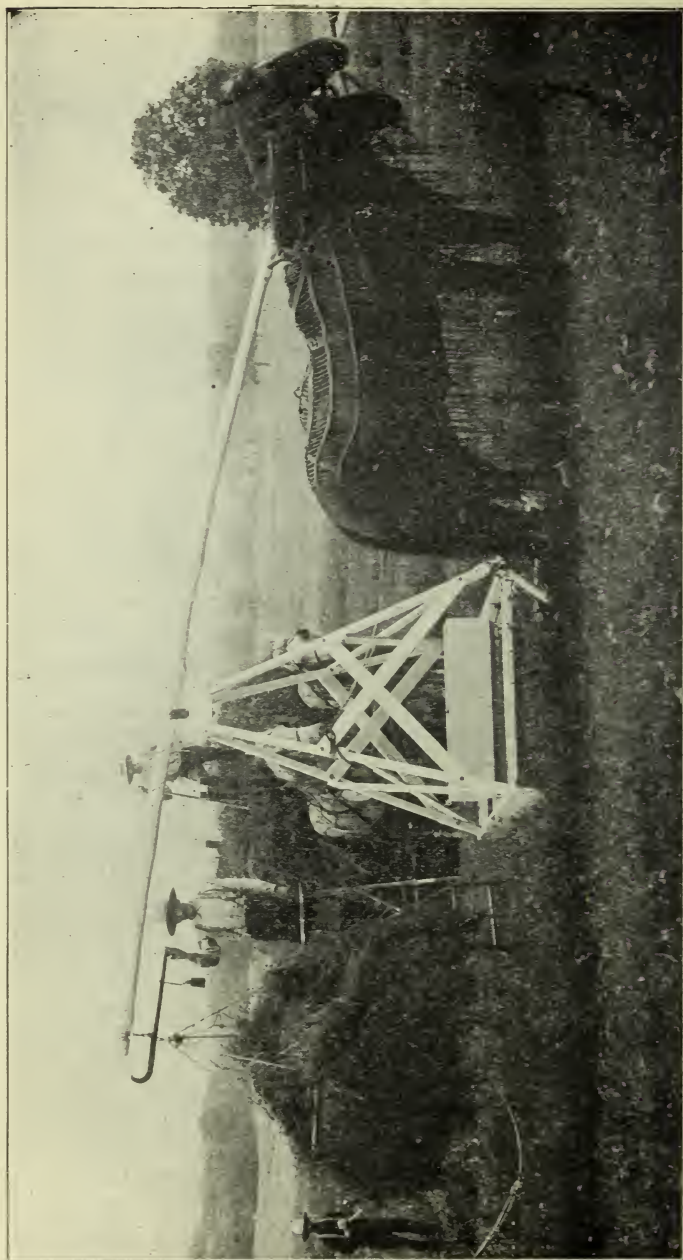
The wagon and stock scale of about four tons capacity is found on many farms and is indispensable where feeding experiments are being made. With such a scale the relative weights of grain and straw may be ascertained with a fair degree of accuracy by weighing the grain in the straw on the wagon as it is being drawn to the thrasher and again weighing the grain as it comes from the machine, the weight of the straw being found by the difference.

Several plots may be carried at once by separating them with sheets, reweighing, of course, after each plot is unloaded. In the same manner several plots of hay may be brought in at once, especially if the hay sling be used for unloading.

THE PORTABLE DERRICK SCALE

The portable derrick scale is an implement much less expensive than the wagon scale and at the same time more accurate. It consists of a derrick, similar in construction to the oil or gas well derrick, but only eight feet high and correspondingly light in construction, and mounted on a pair of sled runners.

This derrick scale is especially useful in weighing the corn crop where it is husked in the field, as it may follow the huskers, weighing the stover before it is reshocked, and by means of a light platform or large basket, substituted for the hay sling, weighing the grain as it goes into the wagon. It may also be similarly used for weighing potatoes as they are harvested.



THE DERRICK SCALE

Fig. 17. The sled runners are oak joists two inches thick, ten inches wide and eight feet long; the uprights are of any strong wood two by four inches and eight feet long; at the top they are bolted to a headpiece six inches thick, eight inches wide and eighteen inches long. The swivel or rowlock which carries the pole is made by blacksmith, the ears being one-half inch by two inches, and the tongue one and one-quarter inch in diameter by eight inches long. The swivel rests upon a washer let into the headpiece, and the split key which holds the swivel in place works upon a similar washer fitted in the lower side of the headpiece. The pole is twenty-four feet long and four inches in diameter at the swivel.

REWEIGHING

The most careful people make mistakes sometimes, and the produce of every plot in experimental work—at least the grain and potatoes—should be weighed the second time. To accomplish this the grain as it comes from the thrasher is weighed into sacks; these are tagged with the number of the plot and set aside, to be weighed again when there is less hurry than while the threshing is in progress. In a similar manner potatoes and corn may be gathered into tagged sacks, boxes or barrels, and weighed again. Both potatoes and corn should be separated into large and small, and in the case of corn it is advisable to count the ears, nubbins and stalks, separating these into those which bear one ear, those having two ears and those which are barren.

KEEPING THE RECORDS

PLANS, DIAGRAMS, ETC.

Before a field experiment is begun the land available should be carefully measured and a diagram of the experiment drawn to scale on paper. In connection with this diagram there should be a record book in which should be entered the dates of all operations and other items bearing upon the progress of the experiment, including the final outcome. It is never safe to depend upon memory nor upon field stakes for the plan of the experiment; for memory is proverbially treacherous and stakes are liable to be misplaced or lost. A very convenient way of entering the final results of an experiment which is continued from year to year is shown in the accompanying transcript from an actual record.

TABLE II. METHOD OF RECORDING PLOT WORK

Wheat grown in 5-year rotation of corn, oats, wheat, clover and timothy.

Plot	YIELD PER ACRE						INCREASE PER ACRE					
	GRAIN-BUSHELS			STRAW-POUNDS			GRAIN-BUSHELS			STRAW-POUNDS		
	Season	Total	Ave.	Season	Total	Ave.	Season	Total	Ave.	Season	Total	Ave.
1894	18.54	.....	.....	3 087	.....	.....	-0.42	.....	.....	991	.....	.....
1895	10.83	.....	.....	860	.....	.....	7.83	.....	.....	657	.....	.....
1896	9.04	.....	.....	1 057	.....	.....	7.76	.....	.....	784	.....	.....
1897	30.58	68.99	17.25	3 665	8 669	2 167	20.75	35.92	8.98	2,642	5,084	1 268
1898	33.67	102.66	20.53	3 110	11,779	2,356	17.71	53.63	10.73	1,581	6,655	1 331
1899	22.83	125.46	20.91	2,580	14,359	2,393	17.19	70.82	11.80	1,825	8,480	1 413
1900	11.67	137.13	19.59	1,120	15,479	2,211	10.67	81.49	11.64	977	9,457	1 351
1901	27.25	164.38	20.55	3,565	19,044	2,380	21.31	102.80	12.85	2,778	12,235	1 529
1902	37.33	201.71	22.41	2,710	21,754	2,417	26.97	129.77	14.42	2,045	14,280	1 587
1903	38.25	239.96	24.00	3,405	25 159	2,516	17.95	147.72	14.77	1,777	16,057	1,606

Under "season" is entered the yield for each successive year; under "total" is carried forward the aggregate yield for the entire period up to the date of entry, and under "average" is entered the average yield for the same period.

CORRECTING RESULTS

While it is highly desirable that an experiment should be so conducted that its results may be accepted just as they come from the field, there will sometimes be cases where some correction is needed in order to avoid a statement that would be actually misleading. In the case of corn and potatoes especially it is practically impossible to secure at all times a perfect stand, because of destruction of occasional plants by insects or from other causes. Where such cases occur it has been found better to count the hills or plants and make the corrections on the basis of the average stand actually attained, rather than upon that of the possible full stand. The former method gives results corresponding to the yield actually obtained, whereas the latter one always gives exaggerated results, since it appears that the destruction of a plant gives opportunity for surrounding plants to develop more freely and produce a yield larger than could have been obtained under normal conditions.

Fig. 18. Plan of experiment with fertilizers on corn, oats, wheat and clover, grown in 4-year rotation. Four sections, of ten plots each, in the test. Fertilizers applied to corn, oats and wheat. Plots 8 and 9 manured and fertilized only on corn.

Total constituents in 4 years

1. Unfertilized	
2. Acid phosphate, 160 lbs. per acre	$P_2O_5=68$ lbs.
3. { Acid phosphate, 160 lbs. per acre Muriate of potash, 40 lbs. per acre	$P_2O_5=68$ lbs. $K_2O=60$ lbs.
4. Unfertilized	
5. { Acid phosphate, 160 lbs. per acre Nitrate of soda, 80 lbs. per acre	$P_2O_5=68$ lbs. $N=38$ lbs.
6. { Acid phosphate, 160 lbs. per acre Muriate of potash, 40 lbs. per acre Nitrate of soda, 80 lbs. per acre	$P_2O_5=68$ lbs. $K_2O=60$ lbs. $N=38$ lbs.
7. Unfertilized	
8. Barnyard manure, 6 tons per acre	{ $P_2O_5=40$ lbs. $K_2O=60$ lbs. $N=60$ lbs.
9. { Barnyard manure, 5 tons per acre Acid phosphate, 200 lbs. per acre	{ $P_2O_5=68$ lbs. $K_2O=60$ lbs. $N=60$ lbs.
10. Unfertilized	

CALCULATING INCREASE

An old soil which, from surface indications, is apparently uniform, may nevertheless show considerable variations due to previous treatment. This is shown by the accompanying diagram (Fig. 19), which shows the average yield of four plots which have received for ten years fertilizers containing the same quantities each of nitrogen, phosphorus and potassium, together with the yield of three adjoining unfertilized plots, the plots being arranged as indicated by the numbers. It will be seen that where we assume the variation between consecutive unfertilized plots to be uniformly progressive we get a practically uniform increase from the different fertilizers, but if we should strike a general average of all the unfertilized plots there would be no consistency in the results. The variation in the unfertilized yield in this case was due to the fact that the land occupied by Plot 28 and parts of the adjacent plots was not brought into cultivation until many years after that occupied by the other plots of the series; but about seven years before the test began all had been thrown into the same field, and when the test began there was no superficial indication of previous differences in treatment.

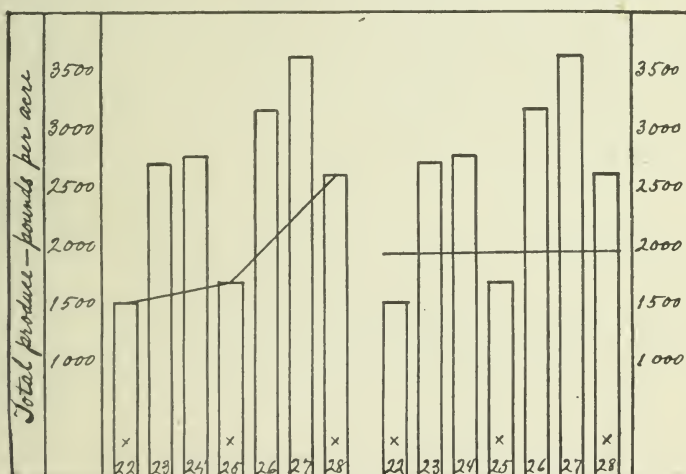


Fig. 19. When every third plot is a check plot the difference in yield between the two successive checks is found, and one-third of this difference is added to the smaller yield of the two checks or subtracted from the larger yield, the result being assumed to be the *natural* yields of the two plots lying between the checks. The difference between this assumed yield and the yield actually obtained is taken as the increase or decrease resulting from treatment.

CONTINUITY OF WORK

Few of the questions which demand solution by field experiment can be definitely answered by a single season's test. The unequal effect of rainfall on soils differently situated with respect to natural drainage may produce wide differences in the apparent results of a test in different seasons. Other climatic variations may produce

similar variations in results, so that an experiment must be carried through a number of seasons before its results can be accepted as a reliable guide.

This point is illustrated by a test showing the increase or decrease in yield of wheat on several plots in 1894, and in the average for ten years. It will be observed that in the general average acid phosphate and nitrate of soda are the most effective constituents of the fertilizer, but that their effect has varied greatly in different seasons, acid phosphate producing an actual loss of crop in 1894. Had this experiment been limited to a single test in 1894 it is evident that a wholly erroneous opinion of the effect of acid phosphate on this soil would have been formed.

Tables III, IV and V show the varying effect of fertilizers over a long period of years on poor soil and on good soil. In most of these seasons phosphorus is unmistakably the chief agent in producing increase of crop; but in 1894, on the poor land, potassium takes the leading place, and in 1903 nitrogen comes to the front, while on the good land there has been still greater variability in the apparent effect of the three fertilizing constituents.

Another reason for continuity of work in experiments with fertilizers is the fact that the full effect of such fertilizers is seldom realized in the crop to which they are applied. This point is shown by Table VI, giving the average increase from fertilizers in a test which has been in progress for ten years, the figures opposite each year being the average result for the entire period up to and including that season. In this case there was a comparatively steady yield on the unfertilized plot, with a constantly increasing yield from the fertilizers.

TABLE III. EFFECT OF FERTILIZERS ON WHEAT IN DIFFERENT SEASONS.

Wheat in rotation with corn, oats and timothy on poor soil.

PLOT	FERTILIZERS	INCREASE (X) OR DECREASE (-) IN BUSHELS PER ACRE	
		1894	10-YEAR AVERAGE
2	Acid phosphate.....	-2.80	× 6.48
3	Potassium chlorid.....	×5.63	× 1.25
6	Sodium nitrate.....	-1.22	× 1.82
6	Acid phos. and nitrate.....	-4.65	×11.40
8	Acid phos. and potassium.....	-1.11	× 8.26
9	Mur. potash and nitrate.....	×3.53	× 2.38
11	Acid phos., potassium and nitrate.....	-0.42	×14.77
12	" " " " " ".....	×0.42	×15.92
14	" " " " " ".....	-1.42	×13.01
15	" " " " " ".....	-1.25	×12.42
23	" " " " " dried blood.....	-0.06	×11.70
24	" " " " " sulphate ammonia.....	×0.89	×11.33
26	Bone meal, potassium and nitrate.....	-3.06	×11.70
27	Dissolved bone black, potassium and nitrate.....	-5.36	×14.37
29	Basic slag, potassium and nitrate.....	-2.08	×13.30

1894 was the first year of the test and was the only season of the eleven years ending with 1904 when the combination of acid phosphate and nitrate of soda failed to produce a large increase.

Table III shows a decrease in yield on all plots fertilized with acid phosphate in 1894 except two. Plots 12 and 24, where acid phosphate, used in combination with other fertilizing materials, shows a slight increase, the gain however being so small as to be almost negligible, yet in the 10-year average acid phosphate has evidently been the most effective of the three materials used in producing increase of crop.

Table IV shows the varying effect of different fertilizing constituents in successive seasons on *poor* soil.

TABLE IV. EFFECT OF FERTILIZERS ON WHEAT IN DIFFERENT SEASONS

Wheat in rotation with corn, oats, clover and timothy on poor soil.

YEAR	YIELD AND INCREASE IN BUSHEL PER ACRE				
	Unfertilized Yield	INCREASE OR (*) DECREASE OVER UNFERTILIZED YIELD FROM—			
		Acid Phosphate Plot 2	Potassium Chloride Plot 3	Sodium Nitrate Plot 5	Plots 2, 3 and 5 combined
1894	19 29	*2.80	5.63	*1.22	*.42
1895	2 98	4 69	*1.02	1.42	7.83
1896	1.06	3 10	.74	.48	7.76
1897	10.43	7.02	1.81	4.83	20.75
1898	12 63	3.70	1.05	2.21	17.71
1899	6.86	5.92	1.91	1.94	17.19
1900	1.08	10.62	.55	1.20	10.67
1901	5.90	17 25	*.17	.11	21.31
1902	10.55	13 06	2.86	1.75	26 97
1903	18.34	2.16	*.83	5.50	17 95
Average.....	8.91	6.48	1.25	1.82	14.77

Injury from Hessian Fly in 1895, 1896, 1899, 1900 and 1901.

Table V shows the varying effect of different fertilizing constituents in successive seasons on *good* soil.

TABLE V. EFFECT OF FERTILIZERS ON WHEAT IN DIFFERENT SEASONS.

Wheat in rotation with potatoes and clover on good land.

YEAR	YIELD AND INCREASE IN BUSHEL PER ACRE				
	Unfertilized Yield	INCREASE OR DECREASE (*) OVER UNFERTILIZED YIELD FROM—			
		Acid Phosphate Plot 2	Potassium Chloride Plot 3	Sodium Nitrate Plot 5	Plots 2, 3 and 5 combined
1895	7.51	7.53	1.06	1.98	8.03
1896	7.42	4.52	1.56	2 63	8 14
1897	34.16	.97	3.11	3.44	8.44
1898	22 99	4 10	2.65	1 21	9.36
1899	25 88	1.53	2 39	2 25	9 75
1900	37.90	4.03	6 30	*1.45	2.33
1901	24 25	3 38	*1.10	*4.13	3.56
1902	36.23	6 83	.26	1.36	16 47
1903	26.75	3.80	*2 69	5.67	11.08
Average.....	4.14	4.19	2 10	1.43	8.57

Injury from Hessian Fly in 1895 and 1896.

Table VI shows the cumulative effect of systematic fertilizing: each season's increase being sufficient to raise the average increase for the total period to a higher level.

TABLE VI. PROGRESSIVE INCREASE FROM FERTILIZERS.

Increase in bushels per acre.

PLOT 11. COMPLETE FERTILIZER	CORN	OATS	WHEAT
Average increase for 3 years ending 1896.....	8 45	12 08	5 06
" " " 4 " " 1897.....	8 74	13 57	8 98
" " " 5 " " 1898.....	10 72	12 92	10 73
" " " 6 " " 1899.....	11 20	14 51	11 80
" " " 7 " " 1900.....	12 60	15 92	11 64
" " " 8 " " 1901.....	14 48	17 21	12 85
" " " 9 " " 1902.....	15 18	17 98	14 42
" " " 10 " " 1903.....	15 07	18 33	14 77

SUMMARY

The experiment station stands for organized research, does things impossible to the ordinary farmer, and formulates general principles. The farmer must make the application. The farmer who profits most by the experiment station must himself be an experimenter.

SELECTION OF SOIL

The *geological history* of a soil is of importance as an index to its general character. *Previous management* may have an important bearing upon the results of an experiment, as shown by long-continued effect of manuring at Rothamsted. In *topography* an experiment field should not be absolutely level nor very steep; a broad, gentle slope of 1 or 2 percent, or just enough to permit uniform surface drainage, has been found best.

ARRANGEMENT OF PLOTS

The most convenient *size of plots*, for most purposes, is one-tenth acre. This size is convenient for computation, and holds a sufficient number of plants to eliminate the errors arising from individuality if care be taken in seed selection. The inequalities of soil can be better eliminated by duplicating the test in small plots than by the use of large plots. In *shape*, the plots should be long and narrow. It is well to adjust the width to the convenient use of machinery and to the scheme of drainage.

Surface drainage must be provided for, and this can be most easily done by making the plots comparatively narrow and slightly ridging them. *Underdrainage* is absolutely necessary on moist soils. *Division spaces* need not be more than 2 feet wide, provided they are the dead furrows made in ridging the plots. *Old ridges and dead furrows*, when running lengthwise of a plot, may reverse the results

of a test, hence plots should be laid out across the direction of previous plowings. *Cross drainage* should be carefully avoided in fertilizer tests. *Cross feeding* may be prevented by separating the plots by dead furrows. The repetition of *check plots* is a matter of first importance. Every third or fourth plot should be used as a check. The *boundaries* of every block of experiment plots should be permanently marked with stakes that will not be thrown out in plowing. *Headlands and roadways* should be left around every block of eight or ten plots, so that teams may be turned without trampling the plots, and every plot should be distinctly marked with a label stake.

PREPARATION OF LAND FOR CROPS

Uniformity of treatments is of first importance. A difference of a few days or weeks in date of plowing may cause as great a difference in yield as any difference in variety or fertilizing. *Manures and fertilizers* should be applied by machinery with special care to get each application wholly on its plot and uniformly distributed. Lime may be applied with a special lime distributor or with manure spreader. All *machinery should be accurate*, whether for seeding, harvesting or thrashing. *Selection of seed* is a matter of importance. Seed of low vitality will not give a proper stand, nor will seed that is uneven in size, hence the tips and butts of seed corn should be rejected and the small grains should be graded. *The rows should be straight*, especially with the small grains, for when the rows crowd each other the yield will be reduced. *The entire plot should be planted*, and to accomplish this the small grains should be drilled beyond the plots, cutting away the excess before harvest.

PLANTING AND CULTIVATING

Machine work is preferable wherever it can be employed, as it is more accurate and uniform than hand work, whether for planting, cultivating, harvesting or thrashing.

HARVESTING

Grass plots may be mown by driving the machine to stakes set so that the nose of the machine will just reach the outer edge of the plot. For *harvesting grain crops* the plots should be arranged in blocks of eight or ten, with 12-foot roadways between, so that the machine may not be driven over the plots except when actually cutting. In all cases a gleaner should follow the machine, to keep the produce of each plot on the plot itself.

WEIGHING

Hay and grain may be weighed on the ordinary wagon and stock scale. Several plots may be loaded on the wagon, separating them by sheets, and weighing again after each one is unloaded; but a

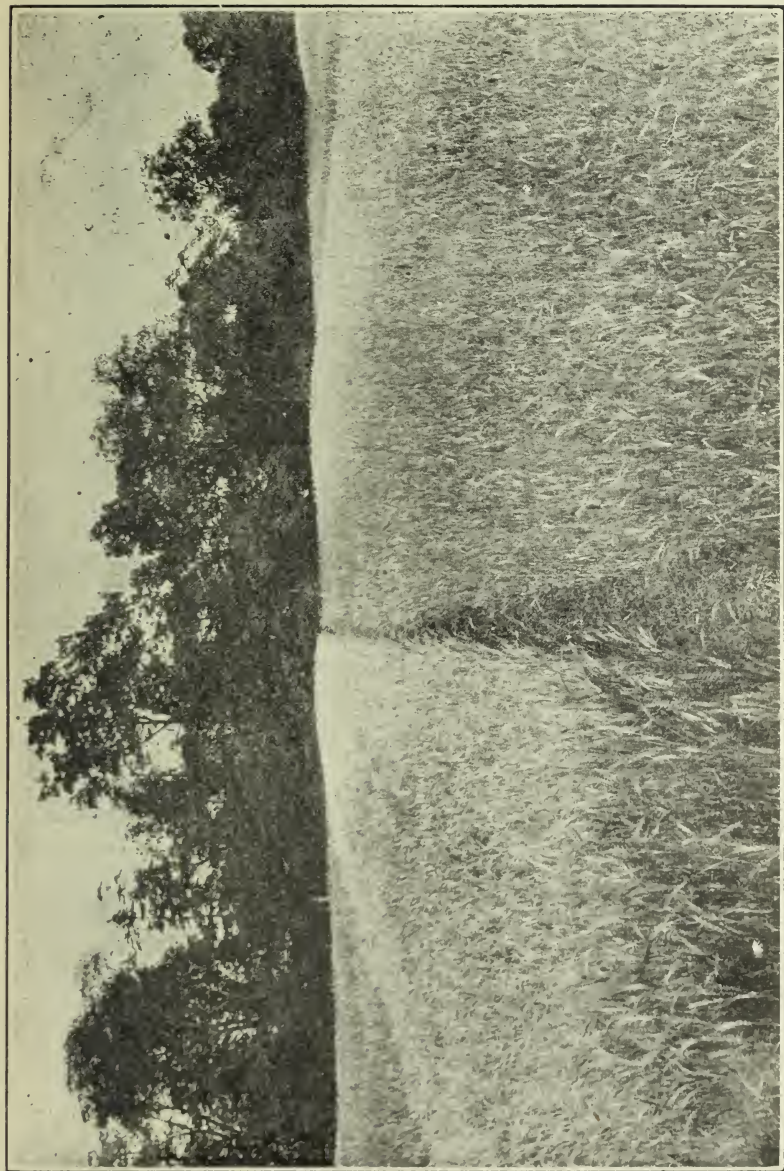
cheaper and better weighing arrangement is the *portable derrick scale*, a common weigh beam suspended to the shorter end of a long lever, which is pivoted on a small derrick carried on a sled and moved from place to place as needed. All weights of grain or potatoes should be verified by setting the produce of each plot aside in a tagged sack or barrel and *reweighing* at leisure.

KEEPING THE RECORDS

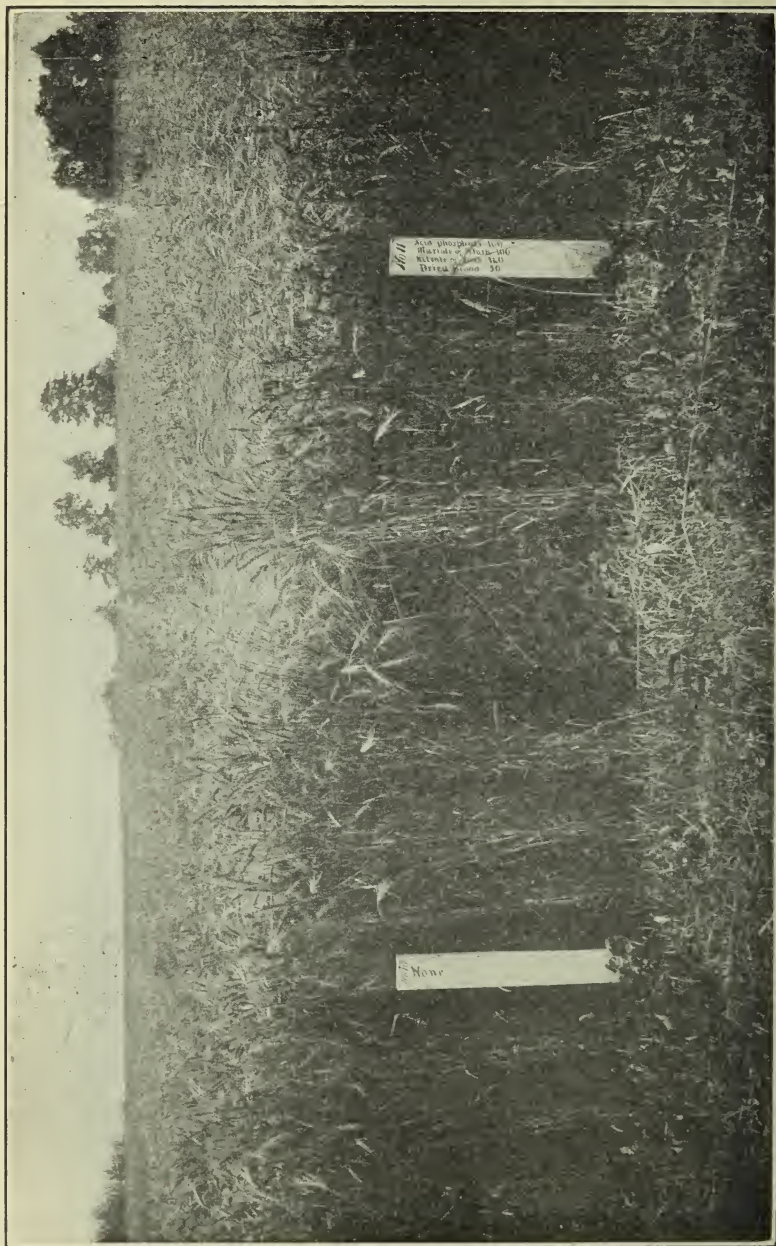
A complete *plan* of each experiment should be made on paper before the work in the field is begun, and every operation should be entered in a record book kept for the purpose. It is sometimes necessary to *correct the results*, and it is better to base this correction upon the average actual yield rather than the possible full yield. The *calculation of increase* should be made on the assumption that the variation between neighboring check plots is due to similar variations in the soil between them. It is never safe to assume that one or two check plots will sufficiently indicate the character of the soil of a large field, nor that the general average of a series of such plots will do so.

CONTINUITY OF WORK

This is of first importance in field experiment. The result of one season's test may be the direct opposite of the average outcome of a period of years, and as a general rule the full effect of the fertilizer or manure can only be determined after a series of years.



Plots 6 and 7 in 5-year rotation, 1905. Yield per acre: Plot 6, 21.33 bushels; Plot 7, 4.42 bushels. A part of Plot 5 is shown in the upper left hand corner, and of plots 8 and 9 in the right hand corner, with a small part of Plot 11 at the extreme right.



Plots 10 and 11 in Potatoes-wheat-clover rotation, 1906. Yield per acre: Plot 10, unfertilized, 46.46 bushels.
 Plot 11, complete fertilizer, 52.33 bushels.

Ohio Agricultural Experiment Station

CIRCULAR No. 97

WOOSTER, OHIO, JANUARY 30, 1910

THE WORK OF THE DEPARTMENT OF COOPERATIVE EXPERIMENTS

BY L. H. GODDARD

INTRODUCTION*

"The experiment station is the distinguishing feature of the new agriculture. It stands for organized research in agriculture; for the concentration of the skill and energy of the entire State on the solution of the unsettled problems of the farm.

"The experiment station is created to do things which are impossible to the ordinary farmer. It is furnished with costly equipment and conducted by men trained in the methods of scientific research, who are made free from other cares in order that they may devote their undivided energies to helping the farmer.

"But while there are some things which can only be done by the aid of such an equipment as that of the experiment station, there are other things which the station can never do, and the farmer who profits most by the work of the experiment station is he who is himself an experimenter.

"It is the province of the experiment station to discover and formulate general principles. The application of these principles must be made by the farmer himself. Even were there an experiment station in every county, there would still be hundreds of farms within each county on which some of the conditions would vary from those of the station, and while no farmer should attempt to duplicate the elaborate work of the experiment station, neither can any farmer afford to blindly accept the conclusions reached at the experiment station without subjecting some of them to the test of further investigation on his own farm.

"Were there no other reason for this than the benumbing effect upon the intellect produced by the unthinking acceptance of the dicta of others, as evidenced by the unnumbered centuries during which the sickle remained unchangingly a chief implement of husbandry, this unchangeableness symbolizing a similar monotony in

* By Director C. E. Thorne, Circular 96, Ohio Experiment Station.

the farmers' intellectual processes, that alone would be abundantly sufficient. The farmer of today must learn to think or he is lost, and nothing is more conducive to exact thinking than scientific experiment.

"The experiment station should carry its work far enough to demonstrate clearly the lines which practical application must follow, but after it has reached its uttermost limit there will still be much for the farmer to do."

ORGANIZATION

In order to help the farmers of Ohio derive a greater benefit from the work of the experiment stations and other similar institutions, there was organized at the Ohio Experiment Station in 1904 a Department of Cooperative Experiments, the immediate purpose of which was to assist in the making of experiments on the farms throughout the State, as suggested above.

In the earlier years, partly because of limited funds, the work of the Department was confined quite largely to field experiment work, in which small plots of one-eightieth acre or less were used, and for which arrangements were made almost entirely by correspondence. Thus was continued, with but slight change, the experiment work of the Agricultural Students' Union,* which, by special arrangement with the Union, was taken up by the Experiment Station upon the organization of the Department. At the present time the Department's functions have come to include, in addition to a modified form of this experiment work, fair exhibits and farm management investigations. In the following pages will be outlined the work as it is proposed to conduct it in 1910, providing the necessary funds are appropriated by the legislature at its present session.

FIELD EXPERIMENT WORK

In the field experiment work of the Department great care is taken to see that the experiments are so outlined that they will fit into regular farm work. It is of course recognized that no experiment worthy of serious consideration can be made which will not require some extra work and attention. But on the other hand, one who is familiar with farm conditions and experiment work as well, can usually plan an experiment which will be fairly easy of execution and yet quite valuable to the farmer, even though it may not be of special value as a scientific investigation. The assistants in charge of the field work of the Cooperative Department have all had experience as farmers. In planning cooperative experiments they always aim to make primary the immediate interests of the cooperator and his neighbors.

* See Bulletin 88 and Circular 47, Ohio Experiment Station.

It is deemed that the adaptability of a given method or variety of a crop to a section is finally determined by its adoption or nonadoption by the farmers of that section after they have had the opportunity to study it in a field experiment on their own farms under their own control. No set of figures from experiments conducted elsewhere is nearly so convincing to most farmers as a local field trial of this kind. It is in the province of the scientific departments of the Experiment Station to conduct scientific field experiments on land which it either owns or controls and to report the results of the same to the world. But the province of the Cooperative Department, so far as field experiments are concerned, is largely to assist the farmers to make experiments themselves on their own farms. The Department helps them by outlining plans and furnishing part or all of the material for the experiment, but the execution of the work is entirely in their own hands. The experiments used in this work may for convenience be classified as follows: small plot, large plot, observation and quantitative. With these experiments may also be classified the multiplying work.

Large and small plot experiments. The large and small plot experiments are, as the names indicate, simply those in which the plots used are either large or small. In either case the size of the plots vary. The smallest plots are probably those used in the potato variety test, in connection with which enough seed of each variety is supplied to plant two rows, each two rods long. In the large plot tests the plots vary in size from one-tenth to one or more acres. The size of the large plots in all cases is determined by the conditions under which the test is to be made. It is the aim, for instance, to make each plot one or more drill or planter rows clear across the field; or, to make the entire test utilize a given area which is specially suited by location or otherwise to the purpose. In most cases material will not be supplied for a large plot test unless a representative of the Department has first visited the site of the proposed work and arranged with the manager regarding all the details.

The observation test. The observation test is one regarding which the report to the Experiment Station is based upon the judgment of the cooperator, no exact figures as to weight of produce being required. Quite a large percent of the cooperative field tests come in this class. It is specially adapted, for instance, to trying out a number of varieties of wheat or oats that have never been grown in a given section. By watching closely the habit of growth of a number of different varieties of these crops for a few seasons, even on small plots, a close observer can easily pick out the poorer ones for the existing conditions, and can then limit further

and more careful experiments to the better ones. The plots of the observation tests are not always small. In connection with the pasture work, for instance, they are frequently an acre or more in size. This depends partly on the nature of the test and partly on the conditions under which it may be made.

The quantitative test. The quantitative tests are those regarding which the cooperator is asked to determine, in pounds or some other appropriate standard of measure, the exact quantity of crop produced on each plot. They are of course the hardest of all for a farmer to make, yet one of the most popular of the Department's tests is that with the potato varieties, which has small plots so arranged that the results are of much scientific value. A modified form of the observation and quantitative tests is that in which one or more small areas of each of the large observation plots are harvested separately and exact weights of produce on same determined to serve as a check on the judgment of the eye in making the observation report.

Multiplying work. After having determined by field experiments that a certain crop or variety of crop is suited to their soil and conditions, most farmers will wish to establish that crop on their farms. In case it is a cereal crop they can do this by purchasing seed from a grower of it with whom the Experiment Station will try to put them in touch. The name and address of the individual or firm from which the Station procured the seed which it uses in cooperative work is always given on the shipping order, a copy of which is always sent to the experimenter with his material.

In case the crop is produced by the Station itself, it will undertake to help cooperators establish the same on their farms, by supplying them without expense with a small amount of the seed, with the understanding that they will take all reasonable care to keep the seed as pure as it was supplied to them, and will sell the produce of it, as soon as their own wants have been supplied, at reasonable prices, to their neighbors or to others who may be referred to them. The Experiment Station itself will sell no seed, but if farmers wish to procure seed in larger quantities than the Station can supply in this multiplying work, they can in many cases secure it from persons to whom seed has been supplied for multiplying purposes in former years.

The work as conducted in 1909, for which the Station supplied part or all of the material, and which will doubtless be continued without material change in 1910, includes the following lines:

LINES OF FIELD EXPERIMENT WORK

Kind of Work	Small Plot	Large Plot	Observation	Quantitative	Multi-plying
Corn	S	L	O	Q	M
Wheat	S	L	O	Q	M
Oats	S	L	O	Q	M
Soybeans	S	...	O	Q	M
Potatoes	S	...	...	Q	...
Fertilizers	S	L	O	Q	...
Lime.....	S	L	O	Q	...
Alfalfa.....	S	L	O	Q	...
Grasses	S	L	O	...	...
Formalin for oat smut.....	...	L	O	...	...
Tanglefoot for canker worm.....	S	...	O	...	...
Strawberry	S	...	O	...	...
Plant Breeding.....	S	L	...	Q	...
Forestry	...	...	...	...	...
Miscellaneous.....	...	...	...	...	...

The work in connection with each of the items listed usually includes several different features. For instance, with corn there are grain and silage variety tests, tests of thickness of planting and date of planting, breeding work, etc. Persons interested in any of the crops or work named, and wishing to take up work along any line regarding them, should write to the Station for details for which there is not space in this circular. As indicated by the term "Miscellaneous," the work is not necessarily limited to the above named features. It is the Experiment Station's desire to help farmers, so far as possible, along all lines in which they are interested. All are therefore invited to communicate their desires to the Station, even though not referred to in this list, and if possible special tests will be planned for them. If it should not be possible to grant the request no harm will be done. The forest-tree planting work, which for a number of years was conducted through the Cooperative Department, has now grown to such proportions that in 1909 the Department's only connection with it was that in regard to shipping, and even this will probably not be necessary in 1910. The alfalfa and grass work has been and probably will continue in cooperation with the Office of Seed Distribution of the Bureau of Plant Industry, United States Department of Agriculture.

County tests. A very interesting phase of the corn work in 1909 was the large plot variety tests, which were conducted in cooperation with a number of the county corn improvement associations. In these tests each grower of good corn in a given section was invited by the Association in that section to supply a sample of his corn to be tested for yield in a field plot test, side by side, with that

supplied by the other growers of his section and with varieties from a distance which were supplied upon request by the Experiment Station. Strange as it may seem, the different varieties that are in use in the same neighborhood will vary in yield from each other from 15 to 35 bushels of grain per acre, when planted side by side in a field test in this way. This work includes silage as well as grain production. In all, fourteen counties took up the work in 1909—Butler, Warren, Mercer, Logan, Putnam, Van Wert, Huron, Lake, Columbiana, Franklin, Hardin, Fairfield, Belmont and Meigs. A number of these counties had duplicate tests, one having the work duplicated on fourteen different farms.

County field meetings. A valuable feature in connection with these tests is the small field meetings at which all persons interested in the test, together with a representative from the Station, gather several times within the crop season to examine and make record of the condition of the various plots. It is probable that the greatest value of a corn show is to get farmers together to talk corn, also that after the first few shows in a neighborhood the actual judging of the corn and the awarding of prizes is more or less of an injury because of the inability of the judge, after the farmers have improved their corn to a certain point, to determine which is really best. In these county field tests the judging is done by the soil, thus robbing the meeting of the injury above mentioned. On the other hand, there is a better opportunity to talk corn with the growing plants before them than there is at a corn show. This work should be considered carefully by every association in the State before determining upon plans for 1910. It need not be confined to corn alone. Tests with potatoes were also taken up in a similar manner in 1909. It may be well to include fertilizers, alfalfa, grasses, soybeans or any other suitable crop.

FAIR EXHIBITS

For a number of years the Experiment Station has been making exhibits at county fairs. These exhibits are not of the kind made by individuals. They do not enter into competition for prizes, but are to illustrate in a concrete manner the improved methods that have been developed by the Station for increasing the net value of crop and animal production. So far as possible, the actual material regarding which the information is to be given is used in making up the exhibit.

For this exhibit there is needed a well-lighted building or tent not less than 40x60 feet in size. A representative of the Station is always on hand the Monday morning preceding the fair to install

the exhibit, and throughout the busy days of the fair the Station provides three or four men to explain the exhibit to those interested. All this is without expense to the county agricultural society other than that connected with supplying the building or tent, drayage to and from the railway, lumber for shelving, carpenters, etc.

In 1909 two exhibits were maintained in the field throughout the fair season—twenty fairs being reached. In the estimate which has been presented to the legislature for the work of the Cooperative Department in 1910, provision has been made for a third exhibit. Further information regarding the fair exhibit work will be given in a circular which is now being prepared and which will be supplied upon request as soon as issued.

FARM MANAGEMENT INVESTIGATIONS*

The Cooperative Department is also making a study of the rotations, cropping, feeding and business methods that are in use upon the farms throughout the State. If the farmers of Ohio are to keep pace with the advancing prices of land and labor they must not only have the best crops and livestock for their conditions, but they must also use the best methods in handling them. It is probable that all these are being used, in piece-meal at least, somewhere within the state. To find these practical illustrations of advancement and introduce them to all is what the Department is undertaking to do.

Cost of production. In order to determine the cost of production of crops and livestock, a number of farmers are reporting to the Station in detail regarding each half-hour of time and each cent of money expended on their farms and all income therefrom. Cooperators in this work are supplied with suitable blanks and receive monthly statements for their farms showing the distribution of labor by field, by operation and by crop or enterprise, and, later in the season, a summary for the important crops.

Enterprise work. A number of other farmers are reporting this information regarding a single enterprise on their farms, such as the dairy, the poultry or a single crop. In the *dairy* work each cooperator is supplied with a Babcock milk tester, scales, sampler, blanks, etc., and reports each month the produce of and the feed consumed by each cow in his herd. On the basis of these reports the Department prepares and supplies to the cooperator each month a statement showing the total pounds and value of milk and butterfat produced and of feed consumed by each cow.

O.] * A part of this work is in cooperation with the Office of Farm Management of the U. S. D. A. Bureau of Plant Industry.

Circulars are now being prepared regarding the dairy work up to the present time, the varieties of corn now being grown in the state, the cropping and business methods used in growing orchard grass, and regarding minor farm equipment. As soon as issued these will be mailed upon request.

Farm examinations. Hereafter upon request the Station will undertake to have a representative visit farms throughout the State, to make a study of them and outline cooperative experiments which will enable the farm manager to determine for himself with accuracy whether or not changes in his plans or methods are advisable. Applicants for these examinations must not expect to receive off-hand advice. Counsel not based on complete and accurate information such as these experiments, considered in connection with experiments made elsewhere, will afford, usually would be of little value. Applications should be made as far in advance as possible, so that visits may be made in circuits to save time and expense.

Agricultural survey. All the information that may be gathered by any phase of the Department's work will be assembled from time to time to contribute to an agricultural survey of the State, which is now being conducted by the Experiment Station. For some time, in furtherance of this end, and because of the diversified conditions existing in many of the counties, all reports to the Department have been recorded by township instead of by county. In this connection may be mentioned a circular, now being prepared, which will show graphically, by township, the statistics of farm products for the whole state, and which is based upon the statistical reports made to the State Board of Agriculture by the township assessors.

Messrs. M. O. Bugby, Gail T. Abbott, W. A. Lloyd and W. M. Cook have charge of the cooperative field work in separate districts of the State, and also of certain phases of the farm management investigations that have been assigned to them for study and report. Mr. W. L. Elser has charge of office record and statistical work.

The preceding statement of the work of the Department of Cooperative Experiments has necessarily been made brief. It is hoped, however, that all persons interested will be so kind as to give the Station an opportunity to explain further regarding any phase of it.

Ohio Agricultural Experiment Station

CIRCULAR No. 98

WOOSTER, OHIO, FEBRUARY 1, 1910

MINOR ITEMS OF FARM EQUIPMENT

INTRODUCTION

This circular regarding the Minor Items of Farm Equipment, which has been prepared by Mr. L. W. Ellis of the Office of Farm Management Investigations, United States Department of Agriculture, Bureau of Plant Industry, in cooperation with the Ohio Experiment Station, is based entirely on inventories taken either by himself or by members of the Ohio Station staff upon thirty-three Ohio farms that are well distributed throughout the State. It would seem, therefore, that his statement that "The minor items for a general farm of 160 acres in Ohio and other Middle-Western States will probably cost from \$200 to \$300 by the time the equipment is complete," instead of \$25 to \$50, as many of us have assumed, should at once challenge our serious consideration. An error of five hundred percent or more in our calculations, especially when it is on the wrong side of the account and runs into the hundreds, is indeed serious, and surely the suggestion by a good authority that such an error does exist should inspire many of us to check the figures that have been given us with the conditions upon our own farms.

In order to facilitate this checking it has been arranged to have the tables on pages 11 to 15 inclusive set with two extra blank columns marked "Number" and "Price of Each" respectively. It is hoped that a few of Ohio's progressive farmers will use these columns to take an inventory of their own minor equipment and that they will favor the Experiment Station with a copy of same. If the original is sent to the Station it will undertake to have the computations made and to return a copy to the sender. If more inventories are received than can be cared for promptly the originals will be returned to the senders without delay. Any variation from the figures or totals as given by this circular will not be taken as captious criticism either by the United States Department of Agriculture or by the Ohio Experiment Station. Both institutions wish to know the facts. The present statement is based on inventories from thirty-three farms only. If figures from a much larger number of farms can be secured the value of future deductions will be correspondingly increased.

L. H. GODDARD.

MINOR ITEMS OF FARM EQUIPMENT

By L. W. ELLIS

Among the leaks in farming to which—because of their apparent unimportance—little attention has been directed, is the waste which occurs through a general lack of comprehension as to the extent and value of the small items which are necessary to the smooth running of the farm. This waste exhibits itself in extra expense through the purchase of unnecessary items; loss of time and discounts in buying numerous articles singly or in small lots; loss, theft and rapid depreciation of items considered too insignificant to require systematic care; and, if the farm is insufficiently equipped, in the losses in many directions through the lack or misplacement of equipment at times when it is urgently needed.

A previous publication (*) has to a greater or less extent emphasized all the foregoing points in discussing the advantages to be gained from having on the farm at all times the workshop tools and materials necessary for keeping in a high state of efficiency the equipment upon which the successful management of the modern farm so largely depends. It is the purpose of this circular to lay even greater emphasis upon certain of these points, and to present the results of a study made for the purpose of determining the amount and cost of all minor items of equipment necessary for a farm of general type. This study did not include wagons, machinery, or other articles which through bulk or value would be classed as items of major importance, but was confined to the consideration of the miscellaneous small tools, utensils and sundries usually purchased singly or in small groups at a slight cost per article.

The total cost of the miscellaneous articles is usually much higher than the estimates given by farmers and writers on agricultural subjects but, owing to the great number of small purchases made, is seldom realized except by the few who have made careful inventories at stated intervals. The ignorance of this fact leads farmers in general to neglect an extremely valuable portion of their equipment, and it would probably be found that the decrease in value of the small articles is much more rapid than that of the

* U. S. Department of Agriculture Farmers' Bulletin 347, "The Repair of Farm Equipment". This bulletin discusses the importance of making minor repairs on the farm, and the character and use of tools, workshop facilities and materials for repair work. It will be sent free on application to the Secretary of Agriculture, Washington D. C.

major items, for which an annual rate of depreciation of 7.3 percent has been established. (*) The low estimates regarding this portion of the equipment also prove disappointing to the manager of a new farming venture who finds it necessary to make an increased outlay on this account, attended by readjustment of his plans.

The importance of having a good working equipment in small items, and the absolute necessity for caring for it, are matters which should be apparent to the thoughtful farmer, and need not be dwelt upon further. The waste of time in making numerous special trips for small articles is also apparent, especially so when it is considered that many of these occur in the busiest seasons. This could be avoided to a large extent by taking an inventory during a slack period and replacing all missing items at the next opportunity. Concerning the loss through ignorance of what is needed, however, less has been said, and it is to the requirements in miscellaneous items and the purchase thereof that this circular will be largely devoted.

In selecting the minor equipment for a given farm, consideration must be given not only to the items needed for the care and repair of buildings, fences, machinery, etc., but to those used for the care of livestock, the production of crops, and various other interests of the farm. With every change in type of farm involving a new combination of enterprises a change in minor equipment will be necessary. For each of the many specialized types of farms certain articles will be needed which will not be found on the general run of farms. To attempt to determine the equipment in small items necessary for all these special types is beyond the scope of this circular, which will attempt to cover only those items found in most common use on farms of the general type. By this is meant a farm of moderate size on which both crops and livestock are raised without particular emphasis on the production or disposition of any one product.

The nature of minor equipment will be determined largely by the character of the farm enterprises and the distance of the farm from repair and shopping facilities, while the extent may be governed by the size of the farm, the number of workmen and the financial circumstances of the proprietor. Perhaps both will be influenced most by the latter's attitude with regard to small economies, and his ability to use tools to the best advantage.

* U. S. Department of Agriculture, Bulletin 73, Bureau of Statistics.

CLASSIFICATION OF MINOR EQUIPMENT

For convenience in considering the small items which go to equip the farm they may be classified according to use in connection with different enterprises.

On every farm, however, there are many articles used in the administration of the entire farm rather than for the conduct of any one enterprise. This general purpose equipment would include the articles already mentioned for the repair of the equipment, including the wood working and metal working tools, and certain repair materials such as wood, iron, paint, oil, etc. The weighing apparatus, tools for drainage and fencing, stone working tools, and many items which cannot easily be classified will also be listed as general purpose equipment.

A strict classification of miscellaneous articles according to use cannot be made because of the varying uses to which the same articles are put on different farms. For instance, certain tools connected with the garden, orchard and dairy, may be either household or farm equipment, depending on whether these are enterprises conducted simply for supplying the wants of the family or for the production of marketed products. Butchering tools would come under both classes where animals are slaughtered in excess of the needs of the family. On a majority of general farms, however, the butchering, orchard, garden and lawn equipment would pertain to the household, rather than to the producing enterprises, while the dairy equipment and ice tools might be both household and farm equipment at different seasons of the year.

Certain articles can be attributed directly to the presence on the farm of a given class of livestock, but many others are used in connection with several classes of stock, and still others may be used in connection with the stable rather than with the animals themselves. In consequence, in addition to classifying articles as equipment for horses, cattle, sheep, hogs, poultry, and bees, respectively, there may be a classification designated as "all stock" equipment to include the last named articles. The same thing is true with regard to the equipment for crop production. As in the case of larger machinery there will be a class of "all crop" tools, etc., as well as the items needed especially for corn, hay, small grains, potatoes, or other crop enterprises.

LIVESTOCK EQUIPMENT

The minor livestock equipment will consist of the items used directly for the care and management of horses, cattle, sheep, swine, poultry, bees, etc. The items classified as "all stock equipment"

need not necessarily pertain to all of the classes of stock listed, but are regarded as being for the use of two or more classes, or for the care of the stables or other quarters used by the stock. Under all stock equipment would be included brooms, shovels, forks, rakes, pails, wheelbarrows, etc., used in caring for the stables; baskets and measures for feeding; hand spraying apparatus for sanitary purposes; and such things as blankets, brushes, curry-combs, clippers, halters, ropes, etc., which might be classified either as all stock equipment or as that for some special class of stock, according to the usage of the individual farm.

Under the general head of horse equipment there has been classified for convenience both the items used directly in the management of the animals, and those used in driving or working the same. Since horses are used for both power and breeding purposes it is difficult to separate the items which are used exclusively for the general purposes of the farm. Many of these will be dispensed with on certain farms, and considered necessary on others. Some may be regarded as personal rather than pertaining to the farm business, but since in the management of the farm a great deal of driving is necessary it seems fitting to include under the head of farm equipment the numerous articles needed for the care of the driving stock, vehicles, harness, etc.

The miscellaneous cattle equipment will consist of those few items which will be found on general farms for the management of stock cattle, and on some farms the dairy equipment will be regarded as belonging to the cattle enterprise. In some sections of the country there will be a few extra items on account of use of oxen for draft purposes, but these will not be found on many farms in the western states. On the comparatively few farms where cattle are fitted for show purposes a few articles such as clippers, cabinet scrapers, spoke shaves, etc., will be in demand for trimming the hair, horns, and feet of the show animals.

No veterinary instruments will be recommended under either horse or cattle equipment except the very simple ones which are found in general use. Naturally the farmer who is something of a specialist along any line will wish to equip himself much more heavily than the ordinary one.

The dairy equipment will, of course, vary extensively according to the extent of the dairy enterprise and the disposition of the product. Besides the separator, which is in general use among the more progressive farmers, there are on some farms the machines and utensils necessary for manufacturing cheese or butter on a large scale. From the majority of general farms, however, the

product is usually sold either as whole milk or as hand separated cream. In the case of the sale of whole milk the whole dairy equipment might consist of nothing more than a few pails, a strainer, and several milk cans. For a small part of the year butter may be made upon the farm and sold elsewhere. In such cases a small churn, thermometer, butter bowl, a few butter crocks, milk crocks or pans, a butter ladle, and occasionally a butter print might be added to the former list. For the manufacture on a larger scale of either butter or cheese considerable extra equipment would be necessary, and the farms in this case would probably be classified as other than of the general type. The items already listed may be found on a great many farms where dairying is not one of the principal enterprises, and it is of this type of farm rather than the specialized plants that we wish to treat in this circular.

On farms where only a few sheep are kept one or more pairs of shears are frequently the entire special sheep equipment. Other items such as sheep bells, wool cards, hand clippers, and clipping machines may be included, also a dipping tank and the necessary dip, although several of these items would probably be regarded as major equipment. It is frequently hard to distinguish between the large and small items, but the aim is here to present only the multitude of miscellaneous articles the need for which would not naturally occur to one in the organization of the farm.

The most necessary article used in connection with swine seems to be the ring plier, and the accompanying box of rings. The small portable hog houses might be classed as miscellaneous equipment, and they are of frequent occurrence in the inventories. A snout clipper, tongs, pig forceps, and pig extractors are sometimes useful.

As a rule the poultry equipment on the general farm is confined to a very few items, and on many no special purchases have been made. Where incubators and brooders are bought a number of useful articles are usually included, and it is only occasionally that additional equipment is purchased. There are, of course, many items which would be found in connection with the specialized poultry farm which are omitted, as well as some which should probably be found oftener on general farms.

Bees are classed as livestock for want of a better designation, and where bees are found on the farms there are usually found a number of special items of minor value. Portable houses for storing bees throughout the winter are found in only a few cases and may be listed with the items of major equipment. The various items of bee equipment are illustrated and their use described in Farmers' Bulletin 59.

MISCELLANEOUS CROP EQUIPMENT

The small and miscellaneous equipment for the production and disposition of crops will include some items which pertain equally to several. These are hoes, baskets, shovels, forks, rakes, scythes, etc., but the class of all crop tools is usually small. In addition to the large machinery drawn or operated by horses each crop has several special items. The corn crop has for its special miscellaneous equipment usually a hand planter; a home made seed tester; a seed rack; several corn knives; and husking pegs, gloves or hooks; and frequently also such items as baskets, seed crates, ensilage forks, a seed corn grader, a shock tyer, and a horse for shocking. In cases where the ordinary wagon box is used for husking corn from the stalk a scoop board or patent end gate is a great convenience.

The small grains such as wheat, oats and barley, require certain special articles. A large number of grain sacks is probably the most frequent item in this regard. On many farms will be found the scythe or cradle, and occasionally a flail, the latter home made. A binder cover is a useful item, and is sometimes included in the purchase price of the binder. The scoop shovel, half bushel measure, a bushel basket, etc., may apply to small grains as well as to corn, potatoes, or other crops. A wooden hand rake is frequently a great saver of grain in a field, and a long tined straw fork a great convenience in handling straw in the barn.

In fitting up the barn for convenience in handling hay there will be needed a track and carrier, the single or double harpoon fork, or hay slings, a number of pulleys, a seven-eighths to one inch hay rope, and the lighter half or five-eighths inch trip rope. Some of these items, once they are installed, are regarded as part of the barn fixtures, and left permanently in place. Others especially the ropes and forks, are frequently taken from place to place by tenants, and their frequent renewal justifies classifying them as miscellaneous equipment. Several pitchforks, a hay knife, a scythe and snath, a baled hay hook and a hand seeder are commonly used.

Where potatoes are grown commercially there are frequently a large number of potato boxes or crates, a potato fork, a hand planter and potato scoop. On one Ohio farm where sugar beets were grown the small items included several beet forks, beet hoes and topping knives. In some sections the production of maple sugar and syrup forms an important farm enterprise requiring special equipment. Each crop has a few peculiar items of equipment, and the term "general farm" is broad enough to include many enterprises. The

foregoing classes of equipment will, however, apply to the majority of general farms in the northern and western sections of the United States.

EXTENT OF MINOR EQUIPMENT

For the purpose of ascertaining how much of the miscellaneous equipment discussed would be necessary on general farms, the annual inventories on the farms of thirty-three cooperators in Ohio were made as complete as possible with respect to the minor items. These farms included one poultry, truck and general farm, one large horse farm, and a number on which dairying was the principal enterprise, yet none departed radically from the general type. The average size was a trifle less than 167 acres, and the average equipment, as nearly as it can be determined, is given in tabular form on pages 11 to 15 inclusive.

The table showing the summary of the minor equipment inventories must be studied closely in order to be of the greatest value. Not all the items listed are necessary for a satisfactory farm equipment, and on no farm was a complete list found. No farm combined all the enterprises represented, yet every item in the list was found on one or more of these farms, and a few others were omitted as being of extremely unusual character and unlikely to occur in many cases. Many items which might be called farm equipment because found in farm homes rather than those in town are not included, the aim being to present a suggestive list of miscellaneous farm tools, etc., for the convenience of the farm manager. The use of the various tools is not described, as only the more common have been included and local merchants are usually familiar with all the items listed.

The table is designed to show the relative importance of the various items and approximately what would be required for a complete equipment. The first column shows the percentage of the whole number of farms from which each article was reported in the inventories. It is probable that in many cases there should be a slight increase in the percentage shown, owing to failure to get all the articles on some of the farms. It is believed, however, to be relatively correct as between the different articles. In the second column is shown the average number of each article on the farms which report the same. In the third column is the number which the *inventories* suggest as approximately the average for a well equipped general farm under the conditions obtaining in Ohio. In making up this number it has been necessary to consider the percentage of farms reporting each article, the average number of articles per farm reporting and the same average for the whole number of farms. The suggested number is the nearest whole number to the

mean found between the two averages. For example, the T-handled wood auger is reported from twenty-two out of thirty-three farms, or 67 per cent. A total of 67 augers was found on these farms, or 3.04 per farm reporting, and 2.03 per farm for the whole number. The mean is 2.54 and the suggested number 3. With one or two exceptions no article is included in the third column, however, which was not reported from at least 20 percent of the farms and for which the average per farm, for the whole number of farms, was less than three-tenths. In this way consideration was given to the fact that on some farms certain items are not reported, and to the fact that on farms which do report the various items there are undoubtedly cases in which fewer articles than those found would be adequate. This last is certainly true since in many cases where several tools of a kind are kept, a part are old, and are retained simply for occasional use. The arbitrary basis given was adopted because it was found to mark quite accurately the dividing line between what was considered essential and non-essential by the owners of several well equipped farms. The column containing the number suggested is not necessarily a recommendation as to what will be urgently needed for a farm of average size and type, but it is indicative of the number of articles suggested by the inventory. By carefully considering the needs of the farm the manager can cut down the list materially. The oil cans, wrenches, eveners, etc., purchased with machines were excluded, wherever practicable, from the inventories, hence the suggested number is less in many cases than the real total for such items.

In the fourth column is given a figure for the first cost of the various articles, the price of all being included for reference, even though the the articles are not all recommended for use. The price for the complete article, for example, a tool with handle, is given in most cases. This price has been obtained wherever possible from hardware merchants located in sections from which the inventories are taken. The majority of hardware items were priced by one of the leading hardware merchants of Wayne County, Ohio. Other prices were obtained from Farmers' Bulletin 347. Still others were supplied by various farmers who had purchased or made similar items within a few months of the date of inventory. These prices will, of course, vary a great deal with the location of the purchaser and the quality of the goods. Regarding the latter, however, the point was emphasized in obtaining prices that average figures were wanted for the quality of goods usually purchased by farmers. These prices are merely suggestive and cannot in all cases be relied upon, for the reasons just mentioned.

The total cost of the various items suggested is extended in the fifth column. The total, which seems extremely large in comparison with the usual estimates is, however, not unreasonable if a rather complete inventory is desired. Taking the grand total inventory of items mentioned in this list for all the farms, using the prices given in column four, and dividing by thirty-three, the first cost for the average farm of 167 acres is found to be about \$190.00. The discrepancy between this figure and that for the suggested column may be due partly to incomplete inventories, but more to the fact that the latter contains a large number of single articles for which the mean spoken of on page 10 was a fraction greater than one-half and less than one. The suggested column indicates a rather complete outfit. Neither figure, however, includes any allowance for a stock of materials for the repair of equipment as given in Farmers' Bulletin 347. An expenditure of \$50.00 or more in this connection would save many trips to town for materials, even if the equipment for making use of them were complete. Many items considered useful and necessary might be added to the list in the suggested column, but the purpose of this circular is to establish what might be called a working basis for considering this phase of equipment. The occasional need for many of these omitted items will be apparent and attention is called to the fact that the list in column three contains only 158 out of 240 articles, all of which were considered necessary in certain cases. The initial expense, if all the items were included in the quantity shown in column 2 would be over \$685.00, and it is not an uncommon thing to find farms in the United States on which the actual investment in small and miscellaneous items would be above this figure if all the tools had been bought first hand. The summary of the thirty-three inventories is given as follows:

SUMMARY OF INVENTORIES

Items	Per cent farms reporting	Average per farm reporting	Number suggested	Cost	Total	Inventory*	
						Number	Price of each
General Purpose:							
1 Auger.....	67	3 0	3	\$.25	\$.75	.....	1
2 Awl.....	27	1.9	1	.10	.10	.....	2
3 Axe and handle.....	48	2 1	2	1.25	2.50	.....	3
4 Pinch bar.....	64	1.1	1	.75	.75	.....	4
5 Bench screw.....	55	1.0	1	.60	.60	.....	5
6 Auger bit.....	94	6 7	7	.30	2.00	.....	6
7 Bit brace.....	94	1.2	1	1.50	1.50	.....	7
8 Steel square.....	85	1.1	1	.75	.75	.....	8
9 Bevel square.....	35	1 0	1	.40	.40	.....	9
10 Try square.....	25	1 0	1	.25	.25	.....	10
11 Wood chisel.....	73	4.3	4	.40	1.50	.....	11
12 Compass.....	42	1.0	1	.30	.30	.....	12
13 Level.....	64	1.2	1	.75	.75	.....	13
14 Drawing knife.....	91	1 3	1	.75	.75	.....	14

* These columns have been inserted to assist persons interested in taking an inventory of their own farms as mentioned on page 2.

SUMMARY OF INVENTORIES—Continued

Items	Per cent farms reporting	Average per farm reporting	Number suggested	Cost	Total	Inventory	
						Number	Price of each
General purpose—Continued							
15 Scratch gauge.....	45	1.4	1	\$.40	\$.40	.....	15
16 Gimlet bits.....	55	3.0	2	.20	.40	.....	16
17 Grub hoe.....	21	1.1	..	.50	..	.....	17
18 Claw hammer.....	82	1.3	1	.50	.50	.....	18
19 Hand axe.....	36	1.0	1	.50	.50	.....	19
20 Hatchet.....	70	1.4	1	.75	.75	.....	20
21 Screw driver.....	67	1.7	1	.25	.25	.....	21
22 Log chain.....	82	2.5	2	1.50	3.00	.....	22
23 Wooden mallet.....	36	1.5	1	.25	.25	.....	23
24 Mattock.....	79	1.4	1	.75	.75	.....	24
25 Compass saw.....	42	1.0	1	.30	.30	.....	25
26 Hand saw.....	94	1.7	2	1.25	2.50	.....	26
27 Crosscut saw (large).....	85	1.2	1	3.00	3.00	.....	27
28 Plane.....	73	2.3	2	1.25	2.50	.....	28
29 Iron wedge.....	79	2.5	2	.30	.60	.....	29
30 Tape line.....	39	1.1	1	.50	.50	.....	30
31 Rasp.....	39	1.1	1	.50	.50	.....	31
32 Brush hook or scythe.....	21	1.0	..	1.25	..	.....	32
33 Cant hook.....	42	1.4	1	1.25	1.25	.....	33
34 Chalk line.....	27	1.0	1	.10	.10	.....	34
35 Buck saw.....	10	1.0	..	.75	..	.....	35
36 Carpenters' pinchers.....	30	1.2	1	.60	.60	.....	36
37 Anvil.....	21	1.0	..	10.00	..	.....	37
38 Vise.....	15	1.2	..	5.50	..	.....	38
39 Forge.....	3	1.0	..	16.00	..	.....	39
40 Combination drill press.....	23	1.0	1	4.00	4.00	.....	40
41 Drills.....	27	3.9	4	.50	2.00	.....	41
42 Tinnern's snips.....	18	1.0	..	1.25	..	.....	42
43 Cold chisel.....	73	2.3	2	.20	.40	.....	43
44 Whetstone.....	24	1.8	1	.10	.10	.....	44
45 Screwplate.....	27	1.0	1	10.00	10.00	.....	45
46 Tongs.....	6	2.0	..	.50	..	.....	46
47 Flat file.....	70	2.0	2	.15	.30	.....	47
48 Round file.....	35	1.5	1	.30	.30	.....	48
49 Taper file.....	42	2.2	2	.10	.20	.....	49
50 Oil can.....	30	1.7	1	.10	.10	.....	50
51 Machine oil (gals.).....	61	.8	1	.30	.30	.....	51
52 Pipe wrench.....	24	1.3	4	1.50	1.50	.....	52
53 Monkey wrench.....	64	2.1	2	.50	1.00	.....	53
54 Tool grinder.....	30	1.0	1	3.00	3.00	.....	54
55 Grindstone.....	91	1.0	1	4.00	4.00	.....	55
56 Riveting hammer.....	39	1.5	1	.75	.75	.....	56
57 Sledge hammer.....	33	1.1	1	1.00	1.00	.....	57
58 Pliers.....	67	1.4	1	.50	.50	.....	58
59 Nippers.....	52	1.5	1	1.00	1.00	.....	59
60 Punch.....	33	2.2	2	.15	.30	.....	60
61 Hack saw.....	18	1.0	..	.50	..	.....	61
62 Saw set.....	36	1.0	1	.60	.60	.....	62
63 Maul.....	16	1.0	..	.60	..	.....	63
64 Post hole digger.....	41	1.5	1	1.25	1.25	.....	64
65 Wire splicer.....	11	1.3	..	1.00	..	.....	65
66 Wire stretcher.....	29	1.1	1	1.00	1.00	.....	66
67 Ditch cleaner.....	22	1.0	1	1.25	1.25	.....	67
68 Tile spade.....	31	1.6	1	1.00	1.00	.....	68
69 Brick trowel.....	44	1.4	1	.40	.40	.....	69
70 Plastering trowel.....	6	1.0	..	1.00	..	.....	70
71 Sand sieve.....	16	1.4	..	.50	..	.....	71
72 Pick.....	31	1.9	1	1.00	1.00	.....	72
73 "D" handled shovel.....	31	1.4	1	1.00	1.00	.....	73
74 Long handled shovel.....	13	1.3	..	1.00	..	.....	74
75 Counter scale.....	16	1.0	..	5.00	..	.....	75
76 Spring balance.....	34	1.1	1	.50	.50	.....	76
77 Steelyards.....	28	1.1	1	2.00	2.00	.....	77
78 Platform scale.....	38	1.0	1	8.00	8.00	.....	78
79 Rat trap.....	24	1.0	1	.50	.50	.....	79
80 Steel trap.....	26	2.1	1	.15	.15	.....	80
81 Jackscrew.....	3	5.0	..	2.00	..	.....	81
82 Step ladder.....	45	1.4	1	1.75	1.75	.....	82
83 Ladder.....	52	1.4	1	2.00	2.00	.....	83
84 Farm bell.....	58	1.0	1	2.00	2.00	.....	84
85 Lantern.....	68	1.8	2	.90	1.80	.....	85
86 Hoisting block.....	16	1.2	..	2.00	..	.....	86
87 Barrel.....	71	3.0	3	.75	2.25	.....	87
88 Padlock.....	39	1.8	1	.40	.40	.....	88

MINOR ITEMS OF FARM EQUIPMENT

13

SUMMARY OF INVENTORIES—Continued

Items	Per cent farms reporting	Average per farm reporting	Number suggested	Cost	Total	Inventory	
						Number	Price of each
General purpose—Con.							
89 Paint brush.....	48	3.3	2	\$.30	\$.60		89
90 Whitewash brush.....	26	1.4	1	.75	.75		90
91 Basket.....	52	5.8	4	.30	1.20		91
Household and farm:							
92 Lard press and sausage stuffer.....	45	1.0	1	5.50	5.50		92
93 Sausage grinder.....	48	1.0	1	2.00	2.00		93
94 Hog scraper.....	10	2.8	2	.10	.20		94
95 Hog hook.....	29	1.1	1	.05	.05		95
96 Butcher knife.....	52	2.4	2	.30	.60		96
97 Kettle.....	55	1.7	1	2.50	2.50		97
98 Tree pruner.....	15	1.2	1	1.50			98
99 Pruning shears.....	39	1.3	1	.40	.40		99
100 Crates.....	39	54.7	40	.40	16.00		100
101 Garden rake.....	64	1.2	1	.50	.50		101
102 Hoe.....	88	2.4	2	.40	.80		102
103 Cultivator.....	12	1.3	1	4.00			103
104 Trowel.....	12	1.3	1	.25			104
105 Cold frame.....	3	8.0	1	2.50			105
106 Flat.....	3	3.0	1	.10			106
107 Spade.....	36	1.4	1	.75	.75		107
108 Sprinkler.....	21	1.1	1	.50			108
109 Lawn mower.....	64	1.0	1	4.00	4.00		109
110 Lawn rake.....	21	1.0	1	.40			110
All stock:							
111 Broom.....	9	2.0	1	.30			111
112 Clipping machine.....	15	1.0	1	6.00			112
113 Manure fork.....	42	2.6	2	.70	1.40		113
114 Pail.....	27	4.4	3	.15	.45		114
115 Tie chain.....	18	5.3	3	.25	.75		115
116 Tie rope.....	9	2.3	1	.25			116
117 Hand sprayer.....	12	1.0	1	.75			117
118 Wheelbarrow.....	42	1.4	1	4.00	4.00		118
Horse and driving:							
119 Bit.....	40	2.4	2	.40	.80		119
120 Blanket.....	91	2.8	3	2.00	6.00		120
121 Brush.....	89	2.0	2	.50	1.00		121
122 Currycomb.....	89	2.3	2	.25	.50		122
123 Collar.....	43	2.7	2	3.00	6.00		123
124 Harness oil (qts.).....	34	1.5	2	.25	.50		124
125 Fly nets.....	34	2.8	2	1.00	2.00		125
126 Halters.....	97	6.5	6	.75	4.50		126
127 Muzzle.....	26	1.8	2	.20	.40		127
128 Nosebag.....	14	1.4	1	.50			128
129 Sweat pad.....	37	2.2	2	.35	.70		129
130 Harness punch.....	69	1.2	1	.50	.50		130
131 Riveting machine.....	69	1.0	1	.50	.50		131
132 Rivets (boxes).....	43	1.2	1	.10	.10		132
133 Tie rope.....	81	2.8	2	.15	.30		133
134 Saddle.....	57	1.0	1	10.00	10.00		134
135 Riding bridle.....	23	1.3	1	1.00	1.00		135
136 Snaps.....	23	7.4	4	.05	.20		136
137 Sponge.....	14	2.0	1	.10	.10		137
138 Neck straps.....	43	1.9	1	.75	.75		138
139 Syringe.....	23	1.1	1	.60	.60		139
140 Storm apron.....	17	1.2	1	.75	.75		140
141 Buggy jack.....	40	1.1	1	.75	.75		141
142 Wagon jack.....	14	1.0	1	1.00			142
143 Clevis.....	40	4.3	3	.10	.30		143
144 Chamois skin.....	11	1.0	1	.50			144
145 Dust robe.....	62	1.2	1	1.00	1.00		145
146 Lap robe.....	71	1.6	1	5.00	5.00		146
147 Evener, 2-horse.....	60	2.0	2	1.50	3.00		147
148 Evener, 3 or 4 horse.....	63	1.5	1	2.00	2.00		148
149 Storm front.....	46	1.1	1	4.00	4.00		149
150 Dash lantern.....	23	1.4	1	1.00	1.00		150
151 Neck yoke.....	14	1.6	1	1.00			151
152 Whiffle-tree.....	29	3.1	2	.30	.60		152
153 Whip.....	60	1.4	1	.50	.50		153
154 Whisk broom.....	11	1.0	1	.10			154
Cattle:							
155 Cow bell.....	6	1.5	1	.25			155
156 Calf muzzle.....	3	1.0	1	.20			156
157 Crate.....	3	1.0	1	.50			157
158 Tie rope or chain.....	39	3.9	1	.30	.90		158
159 Dehorning clipper.....	9	1.0	1	6.00			159
160 Milk tube.....	15	1.0	1	.25			160

SUMMARY OF INVENTORIES—Continued

Items	Per cent farms reporting	Average per farm reporting	Number suggested	Cost	Total	Inventory	
						Number	Price of each
Dairy:							
161 Milk can.....	36	4.9	4	\$ 1.50	\$ 6.00	.....	161
162 Milk crock	27	9.9	7	.10	.70	.....	162
163 Milk pan.....	6	5.0	..	.20	.....	.....	163
164 Milk pail.....	70	3.2	3	.50	1.50	.....	164
165 Churn.....	45	1.1	1	4.00	4.00	.....	165
166 Butter crock.....	21	10.1	6	.20	1.20	.....	166
167 Butter bowl.....	21	1.0	..	.50	.....	.....	167
168 Butter scales	6	1.0	..	1.50	.....	.....	168
169 Strainer.....	30	1.0	1	.50	.50	.....	169
170 Skimmer.....	6	1.0	..	.10	.....	.....	170
171 Thermometer.....	24	1.0	1	.25	.25	.....	171
Sheep:							
172 Bell.....	12	5.0	3	.15	.45	.....	172
173 Shears.....	48	1.6	1	1.00	1.00	.....	173
Swine:							
174 Ring plier.....	58	1.1	1	.20	.20	.....	174
175 Rings (boxes).....	..	..	1	.10	.10	.....	175
176 Snout clipper.....	3	1.0	..	.40	.....	.....	176
177 Tongs.....	3	1.0	..	.50	.....	.....	177
178 Crate.....	15	2.0	..	1.00	.....	.....	178
179 Portable house.....	39	6.6	5	4.00	20.00	.....	179
Poultry:							
180 Fountain.....	6	3.5	..	.25	.....	.....	180
181 Feed hopper.....	3	3.0	..	.25	.....	.....	181
182 Trap nests.....	3	8.0	..	.25	.....	.....	182
183 Feed pan.....	3	6.0	..	.05	.....	.....	183
184 Feed sieve.....	3	1.0	..	.25	.....	.....	184
185 Hover box.....	3	6.0	..	.25	.....	.....	185
186 Egg tester.....	6	1.0	..	.15	.....	.....	186
187 Coop.....	3	3.0	..	3.00	.....	.....	187
188 Leg bands.....	6	50.5	..	.....	.....	.....	188
189 Bone cutter.....	6	1.0	..	6.00	.....	.....	189
Bees:							
190 Foundation (lbs.).....	6	6.0	..	.75	.....	.....	190
191 Section box (100).....	12	2.8	..	.75	.....	.....	191
192 Foundation fastener.....	9	1.0	..	.75	.....	.....	192
193 Hive.....	15	19.6	..	1.00	.....	.....	193
194 Super.....	12	30.3	..	.50	.....	.....	194
195 Smoker.....	12	1.0	..	1.00	.....	.....	195
196 Bee escape.....	6	2.0	..	.25	.....	.....	196
197 Bee veil.....	9	1.3	..	.10	.....	.....	197
198 Honey crate.....	6	13.5	..	.25	.....	.....	198
199 Honey extractor.....	6	1.0	..	3.50	.....	.....	199
Corn:							
200 Shock tyer....	27	1.0	1	.50	.50	.....	200
201 Knife.....	70	2.7	2	.25	.50	.....	201
202 Hand planter.....	61	1.3	1	1.50	1.50	.....	202
203 Ensilage fork.....	6	1.0	..	1.00	.....	.....	203
204 Seed tester.....	42	1.5	1	.50	.50	.....	204
205 Seed rack.....	9	1.3	..	1.00	.....	.....	205
206 Husking peg.....	30	2.9	2	.10	.20	.....	206
207 Husking gloves (pr.)...	12	1.3	..	.75	.....	.....	207
Hay:							
208 Stack cover.....	3	2.0	..	8.00	.....	.....	208
209 Carrier.....	30	1.1	1	3.00	3.00	.....	209
210 Hoisting fork.....	58	1.1	1	1.25	1.25	.....	210
211 Pulleys.....	55	4.5	4	.40	1.60	.....	211
212 1-inch hay rope (ft.).....	61	132.5	110	.....	5.00	.....	212
213 ½-inch trip rope (ft.).....	30	65.0	40	.....	.45	.....	213
214 Hand fork.....	88	3.2	3	.60	1.80	.....	214
215 Baled hay hook.....	21	1.6	1	.30	.30	.....	215
216 Scythe and snath.....	88	1.4	1	1.25	1.25	.....	216
217 Hand seeder.....	70	1.1	1	5.00	5.00	.....	217
218 Sickle.....	32	1.1	1	.50	.50	.....	218
219 Slings.....	9	2.7	..	2.00	.....	.....	219
220 Knife.....	67	1.2	1	.75	.75	.....	220
Small grain & seed:							
221 Cradle.....	48	1.0	1	5.00	5.00	.....	221
222 Binder cover.....	36	1.0	1	3.00	3.00	.....	222
223 Flail.....	15	1.6	..	.....	.....	.....	223
224 Measure.....	33	1.4	1	.50	.50	.....	224
225 Straw fork.....	15	1.2	..	.70	.....	.....	225
226 Hand rake.....	36	1.3	1	.25	.25	.....	226
227 Sacks.....	97	38.6	38	.20	7.60	.....	227
228 Scoop shovel.....	82	1.7	2	1.00	2.00	.....	228

SUMMARY OF INVENTORIES—Continued

Items	Per cent farms reporting	Average per farm reporting	Number suggested	Cost	Total	Inventory	
						Num-ber	Price of each
Sugar beets:							
229 Beet fork.....	3	2 0	..	\$1.50	\$....	.....	229
230 Beet hoe.....	3	6 0	..	.50	.....	.....	230
231 Beet topper.....	3	9 0	..	.25	.....	.....	231
Potatoes:							
232 Scoop.....	3	1 0	..	1.50	.....	.....	232
233 Fork or hook.....	39	1 4	1	1.50	1.50	.....	233
234 Hand planter.....	3	1 0	..	1.75	.....	.....	234
Maple sugar:							
235 Sap bucket.....	21	471 0	..	.20	.....	.....	235
236 Spout.....	15	485 0	..	.03	.....	.....	236
237 Cover.....	3	500 0	..	.06	.....	.....	237
238 Scoop.....	12	1 0	..	1.00	.....	.....	238
239 Gathering pail.....	12	2 5	..	.75	.....	.....	239
240 Tapping bit.....	9	2 0	..	.30	.....	.....	240
Total cost of items suggested.....					\$270.70	.....	.....

A careful study of the foregoing list will bring out many points worthy of consideration. To the owner of a farm who has no occasion from time to time to collect the miscellaneous equipment and take account of its extent, this study will probably suggest the advisability of taking an annual inventory of the small as well as the large equipment in order to keep track of his investment. The practice of taking an inventory even of the larger pieces of machinery, is not as common as it should be, and in many cases where an invoice is taken the "small stuff" is lumped in one item. During the process of taking the inventories used in compiling this circular the owner almost invariably expressed astonishment at the extent to which his capital was invested in miscellaneous articles. The tenant farmers, and especially those who have frequent occasion to move, will ordinarily be found better posted as to the extent of the miscellaneous equipment, and the equipment of the latter will usually be found to be much nearer the actual necessities than the equipment of the resident owner. To both of these classes, however, it is earnestly suggested that, following an inventory for the purpose of determining the number and the value of articles on hand there should be provision made for keeping track of the various articles in a systematic manner. Only in this way can loss through theft and carelessness be avoided; time saved through a knowledge of where the articles can be found when wanted; expense through duplication of item when the original article cannot be found for the time being be rendered unnecessary, and depreciation on account of neglect be reduced to a minimum. It is unnecessary to dwell upon these points, as they will be apparent to the business-like farmer.

This list is also suggested as containing possibilities of great value to the prospective farmer. To the average person the compiling of a complete list of articles necessary for use on the average sized general farm becomes almost an impossibility after he has listed the larger items such as machinery, wagons, etc. This applies as well to the man with some farm experience as to the one who engages in it for the first time. The experience of several men, born and raised on the farm and temporarily separated from it during a college course, will bear out this statement. One of these was actually in charge of an experimental farm for four years prior to taking up farming on his own account, yet his initial allowance for small tools and sundries was only \$25.00. After going over an incomplete list similar to the foregoing he purchased a very modest lot of small tools, amounting to over \$100.00 in value, from a local hardware dealer, thereby obtaining a cash discount of 10 per cent.

A recent graduate of the Ohio State University, before engaging in farming on his own account on a portion of his father's farm, kept in mind for four or five months the problem of getting a complete equipment within his means. He first noted all the items which he considered necessary, basing his list on his previous experience. His second step consisted of the task of obtaining the net retail prices of the various articles. The result was a total so large that the third and most difficult step—that of determining the actual necessities—was pursued diligently for a considerable time. Having finally reduced his list to the minimum he entered into negotiations with several of the local merchants. Two of these made special efforts to obtain his order and each made the suggestion that he take a trip at the merchant's expense to one of the cities in the state, and select his equipment from the large stocks in the wholesale supply houses. He accepted one of these offers, and, during the State Fair, spent a half day in a large warehouse selecting the style and quality of articles he desired. The goods were shipped to the local dealer, who obtained his profit and still made a cash discount of 10 per cent from the ordinary prices. The young farmer brought his entire stock of miscellaneous equipment from the store at one trip with a team and wagon, and then spent a day or two arranging his workshop and disposing of his various items in the most convenient places, the extent of his outlay impressing him with the necessity for taking systematic care of the smallest details. Several items which were not up to the standard were taken back and exchanged for perfect goods at the local store, hence the entire outfit was delivered at the farm with very little expendi-

ture of time and annoyance and in perfect condition. By following this method the farmer was enabled to make his selection from well known brands and from a larger stock than that afforded by the ordinary store, besides having a pleasant outing in connection. His total purchase amounted to \$125.00, a part being for household use. The following were charged against the farm business:

1 Leather halter.....	\$ 1.65	Brought forward.....	\$61.05
1 Gallon paint.....	1.50	1 Horse Blanket.....	3.00
1 Gallon barn paint.....	.85	1 Whip.....	.25
1 Bottle "3 in 1" oil.....	.10	1 Monkey wrench.....	.40
1 Smalloy can.....	.05	1 Alligator wrench.....	.25
1 Leather punch.....	.60	1 Paint Brush.....	.15
2 Pair gloves.....	.20	1 Cahoon seed sower.....	4.50
1 Pair shucking gloves.....	.50	1 Saw set.....	.60
1 Shucking peg.....	.20	1 Log chain, 15 feet.....	1.72
1 Riveting machine.....	.50	1 Axe and handle.....	1.00
1 Soldering iron.....	.30	1 Boy Axe.....	.75
1 Crowbar, 16 pounds.....	.64	1 Cold chisel.....	.20
1 Center punch.....	.10	1 Chisel, 3-4 inch.....	.30
1 Draw knife.....	.60	1 Chisel, 1-inch.....	.35
1 Garden hoe.....	.35	1 Rope, 1-2 inch, 50 feet.....	.55
1 Grindstone.....	3.75	1 Hoisting block.....	2.50
1 Buggy robe.....	8.00	1 Tinner snips.....	.35
1 Blacksmith's vise, 5 inch.....	6.00	1 Road scraper.....	5.00
1 Tamper.....	1.00	1 Steel square.....	.85
1 Pair scales, 600 pounds.....	11.00	1 Nail hammer.....	.75
1 Oilstone.....	.50	1 Ball pein hammer.....	.75
2 Gallons of harness oil.....	2.00	1 Jack screw.....	2.25
1 Jack plane.....	2.00	1 Pipe wrench.....	1.50
1 Paint brush.....	.65	1 Currycomb.....	.20
1 Ratchet brace.....	1.75	3 Clevises.....	.24
1 Bit, 1-4 inch.....	.20	1 Crosscut saw and handle.....	2.80
1 Bit, 5-16 inch.....	.20	5 Files.....	.75
1 Bit, 7-16 inch.....	.20	1 Grub hoe.....	.45
1 Bit, 1-2 inch.....	.25	1 Garden hoe.....	.35
1 Bit, 10-16 inch.....	.30	1 Horse brush.....	.45
1 Bit, 12-16 inch.....	.30	1 Horse brush (tail).....	.15
1 Bit, 1 inch.....	.40	1 Hatchet.....	.75
1 Hand saw.....	1.75	1 Lantern.....	.90
1 Hand saw.....	.90	1 Fork, 4 prong.....	.60
1 Hack saw.....	.45	1 Punch.....	.10
1 Compass saw.....	.25	1 Pick and handle.....	.60
1 Pair of pliers.....	1.00	2 Boxes copper rivets.....	.20
1 Pair of pliers.....	.30	2 Boxes tubular rivets.....	.10
1 Post hole digger.....	1.25	1 Spade.....	.60
1 Screw driver.....	.35	1 Ditching spade.....	1.00
2 Shovels.....	1.20	1 Snath.....	.75
1 Scoop shovel.....	.75	1 Scythe.....	.75
1 Plastering trowel.....	.62	1 Wheelbarrow.....	1.75
2 Wedges.....	.40	1 Hay knife.....	.75
1 Fork, 3 prong.....	.65	1 Feed basket.....	.80
1 Whetstone.....	.05	1 Pair nippers.....	.75
1 Mail box.....	1.00	1 Sledge and handle.....	.90
1 Wagon jack.....	1.00	3 Quarts of paint.....	1.15
1 Bucket.....	.95		
1 Set ladder irons.....	1.35	Total.....	\$106.86
12 Bolts, 14-inch.....	.49	Less 10 per cent cash discount.....	10.69
Carried forward.....	\$61.05	Net cost.....	\$ 96.17

A similar course might well be pursued by many persons who are about to engage in general farming. As before stated, the saving through the merchant's discount is considerable. The merchant who furnished the majority of the prices contained in the tables stated that for a large bill of goods such as those under discussion, he could afford to give from ten to twenty per cent discount for cash on account of the size of the order and the saving in the cost of selling. This would pay interest on the investment for some years, to say nothing of the time which would be saved through having the stock complete at the beginning.

On nearly every farm some articles will be found which have been bought second hand, and perhaps others which have been acquired gratis with the place. No doubt a considerable saving may be effected by securing articles at odd times when work is not pressing. If, however, the business of the farm is stopped during attendance at a sale, it is an open question whether the saving on minor items over the suggested method will be sufficient to cover the time spent. As a rule these articles are summed up in the sale bill as "too numerous to mention" and no idea is given as to the extent or condition of the offering.

The lists given are in the nature of a census in that they present data from which the individual may secure the information suited to his own use. They are presented in that light, rather than as a recommendation of what should be purchased. Farmers' Bulletin 347, following a discussion of the various workshop tools, contains this paragraph:

"Shop Equipment:—The complete equipment of a shop for the making of general farm repairs should include the above blacksmithing outfit, the \$25.00 collection of wood-working and general-purpose tools, a pipe-working combination, miscellaneous tools, harness-repair outfit, a workbench, a pair of sawhorses, and a grindstone. This entire equipment for a shop can be secured for about \$100.00 in a fair quality of goods, and for \$150.00 tools of excellent quality can be obtained."

The great quantity of other general purpose items, together with those for use in connection with the producing enterprises, and the stock of materials needed for the repair of farm equipment, will easily bring the total cost of a good working equipment in miscellaneous articles up to \$250.00. The expenditure of this sum for this purpose in the organization of the farm is probably out of the question for many farmers, but due consideration at the outset for the necessary investment in minor items will save much inconvenience and disappointment later.

SUMMARY

Few farmers realize the extent of their investment in the small items of equipment or the time and inconvenience involved in buying numerous articles singly or in small lots. Before planning the farm equipment due consideration should be given to the necessary outlay for minor items, and, where possible, the latter should be secured at one purchase, thereby saving time, and usually money. The purchase of these articles in such a manner will mean a total expenditure sufficient to impress the farmer with the need for their systematic care. The minor items for a general farm of 160 acres in Ohio and other Middle Western states will probably cost from \$200.00 to \$300.00 by the time the equipment is complete.

Ohio Agricultural Experiment Station

CIRCULAR No. 99

WOOSTER, OHIO, MARCH 1, 1910

COOPERATIVE DAIRY WORK

Farm Management Investigations.

By L. H. GODDARD AND M. O. BUGBY

WHICH HERD REPRESENTS YOURS ?

Herd No. 4			Herd No. 6		
Cow No.	Profit	Loss	Cow No.	Profit	Loss
1	\$ 22.91		1	\$ 60.09	
2	14.85		2	49.00	
3	2.79		3	48.89	
4		\$.73	4	47.43	
5		5.56	5	47.32	
6		7.81	6	38.43	
7		8.08	7	36.37	
8		8.74	8	34.02	
9		8.91	9	31.66	
10		11.96	10	26.25	
	<u>\$ 40.55</u>	<u>\$52.79</u>	11	24.43	
		40.55	12	12.57	
Total loss		\$12.24	Total profit	\$456.46	\$ 00.00
Average loss per cow		\$ 1.22	Average profit per cow	\$ 38.04	

How many dairy cows in Ohio are being kept at a profit? In order to study this question and other problems in connection with the dairy and to assist the dairymen of the State in answering it for their own herds, the Experiment Station* began in April, 1907, to loan scales, Babcock testers, etc., and to furnish the necessary blanks and supplies to dairymen on the condition that the following records of each cow be kept and sent to the Station each month: the daily weight of milk, a test of a 6-day composite sample of the milk

* As announced in Circular 67, Ohio Experiment Station.

and the approximate amount of feed used—the amount of feed to be determined by occasional weighings and accurate notes regarding changes in rations. From that time up to the present an increasing number of dairymen have been taking advantage of this opportunity until on February 1, 1910, eighty-one cooperators distributed throughout twenty-six counties of the state were keeping records of eleven hundred and seventy-eight cows.

DISTRIBUTION OF DAIRY COOPERATORS FEBRUARY 1, 1910

County	No. Cooperators	No Cows	County	No. Cooperators	No. Cows
Ashtabula	11	165	Lorain	2	20
Athens	1	8	Lucas	1	12
Belmont	1	16	Mahoning	2	13
Clermont	3	45	Medina	6	60
Columbiana	3	48	Meigs	2	21
Cuyahoga	1	20	Muskingum	2	33
Erie	1	13	Portage	13	179
Franklin	1	16	Seneca	1	13
Fairfield	1	10	Summit	2	32
Geauga	13	185	Stark	1	12
Harrison	1	22	Trumbull	6	130
Hamilton	1	7	Williams	1	25
Jefferson	1	25	Wayne	3	38
			Total—26	81	1178

Until August 1909, after the amount of milk and fat and value of product were computed and added to the original records, these original records were returned to the cooperator. Since that date the original records have been kept for the files of the Experiment Station and an adding machine copy of same returned to the cooperator each month, together with a statement showing the amount and value of milk, fat and feed, and profit over feed,—for each cow, for the whole herd and for the average of the herd.

At first an attempt was made to have the records begin and end with the calendar year, but this did not prove satisfactory, because of the varying lactation periods, of the different cows. At present the records are being kept by lactation periods, a loose-leaf sheet being devoted to each cow for each of these periods. As soon as the lactation period of any cow is complete the results are reduced to a yearly basis that they may be comparable with other cows of the same herd. This, of course, means that the records of the entire herd are never complete at the end of the first year, so a summary of the whole herd cannot be sent to the cooperator at that time, but with the monthly statements at hand he can easily pick out the unprofitable cows.

The fact that many cooperators are discarding their unprofitable cows makes it more difficult to determine the actual condition that existed before the records were kept. The Experiment Station cannot ask that a cow be kept in a cooperating herd after she has been proven to be unprofitable and as a result many of the poor cows do not complete the full year's record, thus making the average of the herd higher than it otherwise would have been. While the

records have not been continued long enough to permit as yet the showing of a distinct gain in many of the herds, it is manifest that such will be the case in the near future. In the herds of the 46 men who have kept the records for at least a year, less than 66 percent of the cows that were in the herds at the beginning are still retained while on the other hand the total number of cows in the herds has increased more than 5 percent. There were 538 cows in the herds when the records were commenced. There are now 566 cows in these same herds. Only 352 of this number were in them at the beginning. In all 789 cows have come under record in these herds within the period of study. This would indicate that the dairymen are getting rid of a large number of cows. Inasmuch as they now know which are the poorer ones, are the results difficult to predict?

On the following pages are given a year's summary of the records of each of six herds which have been in cooperation with the Station for more than a year. The records of some of the cows in these herds are the average of two years. These summaries are given simply to show conditions as they are existing in some of the herds of the State. The question may be raised as to whether the herds reporting to the Station represent the average of the State. We can unhesitatingly say that they do not. They are doubtless above the average. It may be assumed that dairymen who are willing to keep such records and to send them to the Experiment Station are not average. Nearly all of these men have been visited by a representative of the Experiment Station who finds that such is the case. There are often better herds in the community than those of the cooperators and in some instances the herds of the cooperators are about as poor as any in the community though the herd of the average man reporting is above the average of his community. Are the herds summarized on the following pages an average of those reporting to the Station? In answer we would point to the fact that the average pounds of butter fat produced per cow per year of all the cows whose records have been completed is 231.2, while the average of the six herds given is 235.4.

A word of explanation as to the method of arriving at results given in the following tables may be well. The *value of the product* was determined from the price actually received each month; i. e., it is the sum of the actual value of the products each month. This, with the difference in the season of freshening, will account for the fact that some cows which produced a smaller total product than others produced a greater total income. This in itself is a problem well worthy of consideration, but it must be left to a future publication. Whenever the whole product was not sold a valuation was placed on the skim milk or whey,—16 cents per hundred lbs. of

whole milk for skim milk and half as much for whey. The *cost of feed* was determined from the amounts and prices actually given by the dairymen. The "*net other costs*" (*) consists of depreciation, interest, taxes and insurance on the cow and equipment, veterinary bills and labor, less the value of the manure. These were determined as follows. The depreciation of the cow was based on the assumption that the average cow will be useful in the herd for six years and at the end of that time will be worth from \$25 to \$30. The value given by the owner was taken as the value on which all calculations were based. Interest, taxes and insurance were calculated at the rate of 6.6 percent of the average value of the cow. The interest, taxes, insurance and repairs on the building equipment were calculated at 8 percent of \$50,—the estimated average value of such equipment.

Spraying material, medicine and dairy utensils were calculated at the rate of 15 cents per thousand pounds of milk given. Labor was based on an estimate of \$17 for a cow producing 2,000 lbs. of milk and increased at the rate of 50 cents per each additional thousand pounds of milk produced. The manure value was calculated from the amounts of nitrogen, potash and phosphoric acid in the feed consumed, as indicated by average analyses. The valuation taken was 67 percent of that placed on these elements in tankage by the Ohio State Board of Agriculture. The following itemized "*net other costs*" of cow No. 7, Herd No. 5, valued at \$60.00, will illustrate the above.

Depreciation on cow.....	\$ 5.83
Interest, taxes and insurance on cow.....	2.23
Interest, taxes, insurance and repairs on buildings.....	4.00
Spraying material, medicine and dairy utensils.....	1.41
Labor.....	19.03
Total "other costs".....	\$ 33.50
Less value of manure.....	12.50
Net other costs.....	\$ 21.00

Plans are now under way to determine the actual investment per cow and the actual labor cost on the farm of each cooperator, as well as the difference in the sale value of each cow at the end of each lactation period, but the above figures are considered of more value for this preliminary report. The *actual profit or loss* given in the record shows the difference between the actual income and the total cost. The "*Elgin*" *profit or loss* in the last two columns is the difference between the total income, based on 27 cents for butter fat, less the total cost. This price may be considered average for most places in the State. It will be noted that nothing has been mentioned regarding the *value of the calf*. It has been assumed that the cow's share in the maintenance of a sire is about equal to the value of the average calf at birth. The best cows in a

* See Circular 134, Illinois Experiment Station.

herd would in most cases have calves of more value than this. Thus the difference between the best and the poorest cows might be much greater than that shown in the following tables.

HERD NO. I

Cow No	Milk	Fat	Fat	Pro- duct	Feed	Net Other	Total	Actual		Elgin	
								Profit	Loss	Profit	Loss
	Lbs.	Lbs.	%	Value	Cost	Costs	Cost				
1	6,113	331.7	5.42	\$117.53	\$52.04	\$16.78	\$68.82	\$48.71	\$.....	\$30.52	\$.....
2	5,970	280.9	4.70	102.02	38.02	20.70	58.72	43.30	.....	26.67	.....
3	5,824	251.4	4.32	91.54	52.04	16.59	68.63	22.91	.....	8.57	.....
4	3,759	191.7	5.10	70.79	38.24	16.32	54.56	16.23	.....	3.21	.....
5	3,469	199.1	5.74	72.69	42.65	14.98	57.63	15.06	.....	1.68	.....
6	4,523	202.8	4.48	75.28	45.21	16.26	61.47	13.81	.....	.52	.....
7	3,748	169.5	4.52	62.45	42.24	15.37	57.61	4.84	.....	.....	5.85
8	3,707	156.8	4.23	59.14	42.91	15.49	58.40	.74	.....	.....	10.13
9	2,439	140.9	5.77	49.14	35.69	16.19	51.88	.....	2.74	.....	9.94
10	3,407	148.5	4.36	52.55	42.84	15.38	58.22	.....	5.67	.....	12.67
11	4,088	163.8	4.00	58.42	49.58	15.20	64.78	.....	6.36	.....	14.01
Total	47,047	2237.1	....	\$811.55	\$481.46	\$179.26	\$660.72	\$165.60 14.77	\$14.77	\$71.17 52.60	\$52.60
Net	.....	.....	.....	.....	.....	.....	.....	\$150.83	.....	\$18.57	.....
Average	4,277	203.1	4.75	\$73.78	\$43.77	\$16.30	\$60.07	\$13.71	.....	\$1.69	.....

Herd No. 1 shows a difference of \$55.07 between the best and poorest cow. Had this herd consisted of three cows like the best one the net profit would have been near to the same, as shown above. The best half of the herd would have given about the same profit as the whole herd.

HERD NO. II

Cow No.	Milk	Fat	Fat	Pro- duct	Feed	Net Other	Total	Actual		Elgin	
								Profit	Loss	Profit	Loss
	Lbs.	Lbs.	%	Value	Cost	Costs	Cost				
1	7,313	226.1	3.09	\$93.22	\$48.98	\$16.28	\$65.26	\$27.96	\$.....	\$7.49	\$.....
2	6,188	194.7	3.14	71.09	41.19	15.24	56.43	14.66	.....	6.04	.....
3	6,350	203.9	3.21	71.55	44.11	14.07	58.18	13.37	.....	7.03	.....
4	6,602	201.1	3.05	73.81	44.23	16.40	60.63	13.18	.....	4.23	.....
5	6,097	223.0	3.66	69.58	52.93	12.71	65.64	3.94	.....	4.32	.....
6	5,710	177.6	3.11	60.14	40.22	17.23	57.45	2.69	.....	.....	.36
7	5,707	190.2	3.33	72.80	58.67	11.83	70.50	2.30	.....	.....	10.02
8	5,191	165.2	3.18	53.59	40.22	12.37	52.59	1.00	.....	.32	.....
9	5,228	187.8	3.59	56.48	45.42	14.20	59.62	.....	3.14	.....	.55
10	5,235	180.6	3.45	54.37	42.06	17.44	59.50	.....	5.13	.....	2.36
11	4,706	157.9	3.35	52.98	43.52	15.97	59.49	.....	6.51	.....	9.33
12	4,268	140.9	3.30	45.07	45.42	13.57	58.99	.....	10.92	.....	14.12
Total	68,595	224.9	.....	\$777.68	\$546.97	\$177.31	\$724.28	\$79.10 25.70	\$25.70	\$29.43	\$36.74 29.43
Net	.....	.....	.....	.....	.....	.....	.....	\$53.40	.....	.....	\$7.31
Average	5,716.0	187.4	3.28	\$64.81	\$45.58	\$14.78	\$60.36	\$4.45	.....	.....	\$.61

Herd No. 2 is above the average in its locality. The milk is sold to a cheese factory, which accounts for the difference between the "actual" and the "Elgin" profits. Had all the cows in the herd been like the best one, the owner would have made a profit of \$335.52, or about six and one-third times as much as he actually did make. Had he sold all of his cows except the best three he would have made a larger net profit. Had he sold the poorest third of his herd he would have cleared almost one-half more.

HERD NO. III

Cow No.	Milk Lbs.	Fat Lbs.	Fat %	Pro- duct Value	Feed Cost	Net Other Costs	Total Cost	Actual		Elgin	
								Profit	Loss	Profit	Loss
1	5,773	272.4	4.72	\$ 78.76	\$ 28.90	\$ 19.30	\$ 48.20	\$ 30.66	\$	\$ 34.59	\$
2	5,155	202.4	3.93	57.79	28.11	23.30	51.41	6.38	.....	11.49	.....
3	4,854	186.8	3.85	58.47	29.26	25.56	54.82	3.65	1 ..	3.39	.....
4	4,410	172.2	3.90	48.83	26.97	23.35	50.32	.....	1.49	3.22	.....
5	3,957	153.4	3.88	47.58	25.22	23.90	49.12	.....	6.54	.....	1.37
6	3,938	136.5	3.47	44.65	25.47	25.76	51.23	.....	13.58	.....	8.07
7	3,269	113.7	3.48	43.07	28.33	27.97	56.30	.....	14.23	.....	20.38
8	2,450	91.6	3.74	26.66	24.80	16.55	41.35	.....	14.69	.....	12.70
Total	33,806	1329.0	...	\$405.81	\$217.06	\$185.69	\$402.75	\$ 40.59	\$ 37.53	\$ 52.69	\$ 42.52
								37.53		42.52	
Net	.....	.....	.....	.....	.....	.....	.....	\$ 3.06	.....	\$ 10.17	.....
Average	4,226	166.1	3.93	\$ 50.73	\$ 27.13	\$ 23.21	\$ 50.34	\$.38	.....	\$ 1.27	.....

Had the average cow of Herd No. 3 been as good as the best one the net profits would have been eighty times as great as they were. Had all the cows been sold but No. 1, the profits would still have been ten times as great. The young owner of this herd with 25 cows like the best one could make enough clear profit from the dairy alone on a rented farm in ten years to buy a 100-acre farm. It would take him eighty years to pay for the same farm from the profits of a herd of 250 cows no better than the average of his present herd.

HERD NO. IV

Cow No.	Milk Lbs.	Fat Lbs.	Fat %	Pro- duct Value	Feed Cost	Net Other Costs	Total Cost	Actual		Elgin	
								Profit	Loss	Profit	Loss
1	7,269	267.3	3.68	\$ 83.37	\$ 42.16	\$ 19.30	\$ 61.46	\$ 21.91	\$	\$ 22.34	\$
2	5,806	201.9	3.48	71.99	40.61	16.53	57.14	14.85	.....	6.66	.....
3	4,764	196.9	4.13	58.31	38.45	17.07	55.52	2.79	.....	5.27	.....
4	5,175	175.6	3.39	55.66	41.41	14.98	56.39	.....	.73	.....	.70
5	5,406	174.1	3.22	53.34	40.53	18.37	58.90	.....	5.56	.....	3.24
6	4,120	140.4	3.41	41.84	36.49	13.16	49.65	.....	7.81	.....	5.15
7	3,867	148.4	3.84	43.51	36.23	15.36	51.59	.....	8.08	.....	5.33
8	4,048	155.1	3.83	45.98	40.71	14.01	54.72	.....	8.74	.....	6.37
9	5,242	159.8	3.05	50.09	43.05	15.94	58.99	.....	8.90	.....	7.46
10	3,478	113.1	3.25	36.16	36.21	11.91	48.12	.....	11.96	.....	12.02
Total	49,175	1732.6	.....	\$540.25	\$395.85	\$156.63	\$552.48	\$ 39.55	\$ 51.78	\$3 4.27	\$ 40.27
								39.55		34.27	
Net	.....	.....	.....	.....	.....	.....	.....	\$ 12.23	.....	\$ 6.00	.....
Average	4,918	173.3	3.52	\$ 54.03	\$ 39.59	\$ 15.66	\$ 55.25	\$ 1.22	.....	\$ .60	.....
11	7,643	283.7	3.71	97.05	55.10	11.94	67.04	\$ 30.01	.....	\$ 21.79	.....
12	9,580	297.9	3.11	103.94	56.56	12.74	69.30	34.64	.....	26.46	.....
Total	17,223	581.6	3.38	\$200.99	\$111.66	\$ 24.68	\$136.34	\$ 64.65	.....	\$ 48.25	.....

The record of Herd No. 4 began in April, 1908, and cows Nos. 11 and 12 did not enter the herd until December the same year, so the record of the first ten cows ends with March, 1909, and that of the last two with November, 1909. For this reason they have been computed separately. As the prices were somewhat higher the second year the "Elgin" profits are more comparable than the actual. We note that on this basis the herd of 10 cows lost their owner \$6.00, while the two cows purchased within the year gave a profit of \$48.25. These two cows were purchased of a neighbor

who had kept records for several years, so the purchaser knew exactly what kind of cows he was securing. Had the owner of Herd No. 4 sold all but the best three cows at the beginning of the year his profit would have been \$40.55 instead of a loss of \$12.24. However, the records up to date indicate that the second year's summary will be different from the first.

HERD NO. V

Cow No.	Milk Lbs.	Fat Lbs.	Fat %	Pro- duct Value	Feed Cost	Net Other Costs	Total Cost	Actual		Elgin	
								Profit	Loss	Profit	Loss
1	6,456	353.6	5.47	\$125.81	\$ 42.06	\$ 22.53	\$ 64.59	\$ 61.22		\$ 41.21	
2	7,778	349.8	4.49	121.99	39.89	21.67	61.56	60.43		45.33	
3	6,693	339.0	5.06	120.67	42.06	20.90	62.96	57.71		39.28	
4	7,366	362.5	4.92	122.51	38.54	27.22	65.76	56.75		43.90	
5	6,809	318.1	4.67	109.64	39.83	19.98	59.81	49.83		36.97	
6	5,931	319.8	5.39	113.25	42.37	22.50	64.87	48.38		30.97	
7	6,077	307.8	5.06	103.90	35.85	21.00	56.85	47.05		35.98	
8	7,450	308.9	4.14	110.37	41.68	21.89	63.57	46.80		31.75	
9	5,838	299.2	5.12	99.55	33.35	23.09	56.44	43.01		33.68	
10	5,934	305.7	5.15	102.49	37.45	22.03	59.48	43.01		32.55	
11	4,718	256.8	5.44	92.37	31.45	19.53	50.98	41.39		25.90	
12	4,043	215.1	5.32	79.03	30.89	19.36	50.19	28.84		14.36	
13	3,603	195.2	5.42	71.80	30.89	17.94	48.83	22.97		9.64	
Total	78,696	3931.5	.....	1373.28	486.31	279.58	765.89	607.39		421.52	
Average	6,054	302.4	4.99	\$105.64	\$ 37.41	\$ 21.51	\$ 58.91	\$ 46.72		\$ 32.42	

HERD NO. VI

Cow No.	Milk Lbs.	Fat Lbs.	Fat %	Pro- duct Value	Feed Cost	Net Other Costs	Total Cost	Actual		Elgin	
								Profit	Loss	Profit	Loss
1	\$ 6,929	\$ 425.0	\$ 6.13	\$124.21	\$ 43.05	\$ 21.07	\$ 64.12	\$ 60.09		\$ 61.73	
2	5,717	356.4	6.23	104.79	40.29	15.50	55.79	49.00		49.59	
3	6,738	391.6	5.81	112.37	42.83	20.65	63.48	48.89		53.03	
4	6,342	373.2	5.88	109.32	40.97	20.92	61.89	47.43		49.02	
5	7,076	383.6	5.42	113.15	48.92	16.91	65.83	47.32		49.06	
6	5,884	337.6	5.74	99.84	47.76	13.65	61.41	38.43		39.15	
7	6,558	323.0	4.92	94.73	39.58	18.78	58.36	36.37		39.34	
8	6,463	300.4	4.65	89.63	37.42	18.19	55.61	34.02		35.84	
9	5,645	290.0	5.14	82.70	35.50	15.64	51.04	31.66		36.29	
10	5,042	266.9	5.29	76.78	38.74	11.79	50.53	26.25		29.80	
11	7,257	385.2	3.93	84.11	49.20	10.48	59.68	24.43		28.93	
12	3,757	216.8	5.77	61.08	36.00	12.51	48.51	12.57		16.04	
Total	73,408	3949.7	.....	1152.71	500.26	195.99	696.25	456.46		487.62	
Average	6,117	329.1	5.38	\$ 96.06	\$ 41.69	\$ 16.33	\$ 58.02	\$ 38.04		\$ 40.63	

Herds Nos. 5 and 6 have no cows that made a loss and show that it is an easy possibility to have an entire herd which averages as good as the best cow in the first four herds. By eliminating the poorer cows and rearing calves only from the best ones, using a good sire from a known high-producing strain and by purchasing cows of known performance, the first four herds can easily be made to produce as great a net profit as the last two.

The evidence of the foregoing records seems to point to the conclusion that the average dairy cow in Ohio is not a very profitable animal, and that the average dairyman has in his herd cows which are not paying him. The question which is of vital importance to each dairyman of the State is not what the average cow or dairy is producing, but what his own dairy is producing.

It is not even enough that he know what his herd is averaging. He must know what each cow is producing. The only way to find out regarding this is by the proper use of scales and Babcock test. No money or time spent for the dairy will bring in larger net returns than that intelligently spent in keeping accurate records. The question is not whether the dairyman can afford to keep a record, but rather can he afford not to keep one.

One weighing and testing of the milk each year is not sufficient. It should be done at regular intervals; best, at least once each month. While very satisfactory results may be obtained by weighing and testing the milk of each cow once each month, the extra time necessary to weigh the milk each day will bring large returns. Aside from aiding in locating the poor cows in the herd, the daily record will give an added interest to the daily work of the dairy, claiming greater interest, better work and closer attention on the part of the hired labor, and most of all, will do much toward making better and more business-like dairymen of both the owner and his sons.

There are several ways in which these records may be kept,—

1. The dairyman may purchase an entire outfit himself. He can well afford to do so.

2. Several dairymen may club together and purchase an outfit, each doing his own testing.

3. A number of dairymen may organize a cow test association, and by paying a small amount per cow, hire a man to weigh and test the milk of each cow once each month. Several such associations have already been organized in the state and are accomplishing much good. If there is none in your locality, organize one. But if you are to receive the greatest benefit from it do not let the tester do all the work. Weigh your own milk each day.

4. Write to the Experiment Station regarding the loan of an outfit. In continuing its study of the dairy conditions and problems of the state the Experiment Station will continue to loan testing outfits, as it has done in the past, as long as funds are available for the work.

SUMMARY

- 1 A large number of dairymen in Ohio are not making a profit on a part or all of their cows.

- 2 This condition may be remedied by the continued and intelligent use of the scales and the Babcock test.

- 3 The Experiment Station will loan these outfits. Write for conditions and application blanks.

Address
OHIO EXPERIMENT STATION,
Wooster, Ohio.

Ohio Agricultural Experiment Station.

CIRCULAR No. 100

WOOSTER, OHIO, APRIL 7, 1910

THE CENTERS OF AGRICULTURAL PRODUCTION IN OHIO

By L. H. GODDARD

Where are the Centers of Agricultural Production in Ohio?

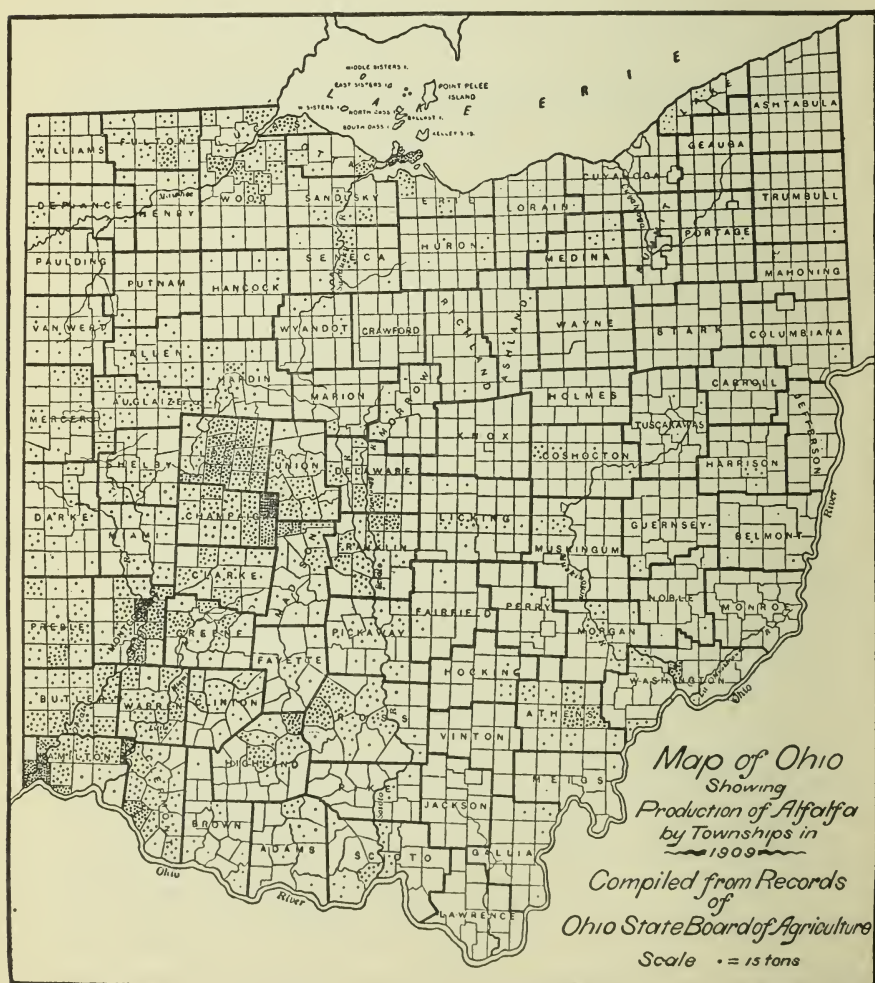
Why are they so Located?

Are they Spreading or are they Contracting?

Are New Centers Springing Up as the Years Go By?

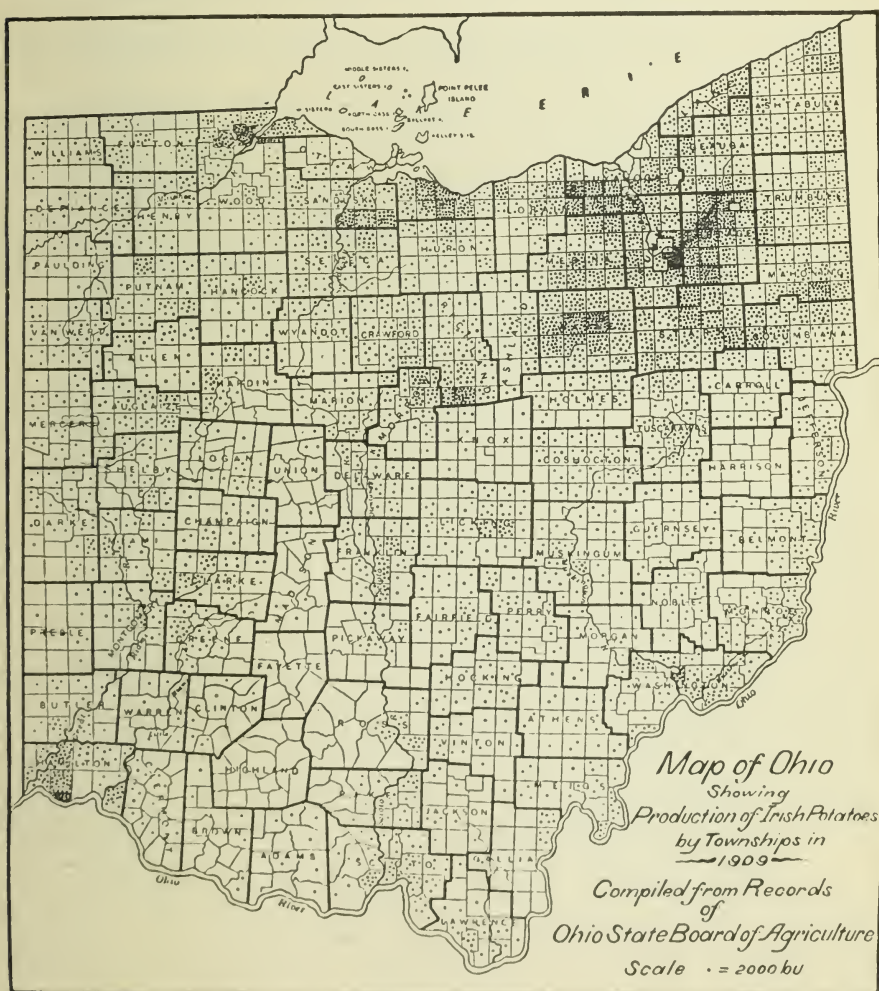
The day has come when progressive farmers wish to know in detail regarding the methods which successful farmers in other sections are following. This fact has long been true of the other professions, but until late years the conservatism of farmers has sufficed to keep them satisfied with the methods that have been handed down to them through several generations of their immediate ancestors. All this has changed now. In these days it is no uncommon experience to meet a farmer who is traveling throughout his State or into other States to observe the crops, livestock and farming methods that are in use on other farms. It is well that this is so. Money spent on such trips of inspection, providing they are well planned, is well spent. An important feature of the work of the Experiment Station is the study of the methods that are used by successful farmers. It is called "Farm Management Investigations."

The planning of these trips of inspection and investigation is not an easy matter. It is undoubtedly interesting and in many cases wise, to study the work of farmers who are successful largely because of their own personality, but in so doing it must be borne in mind that this personality cannot be copied. Unless a farmer is very sure of his own personal ability and resourcefulness in overcoming obstacles which he may meet, it is hardly advisable for him to undertake to follow a new method which he has observed in some other section unless a number of the more progressive farmers in that section have been so impressed with the desirability of the method that they have undertaken and have been able to

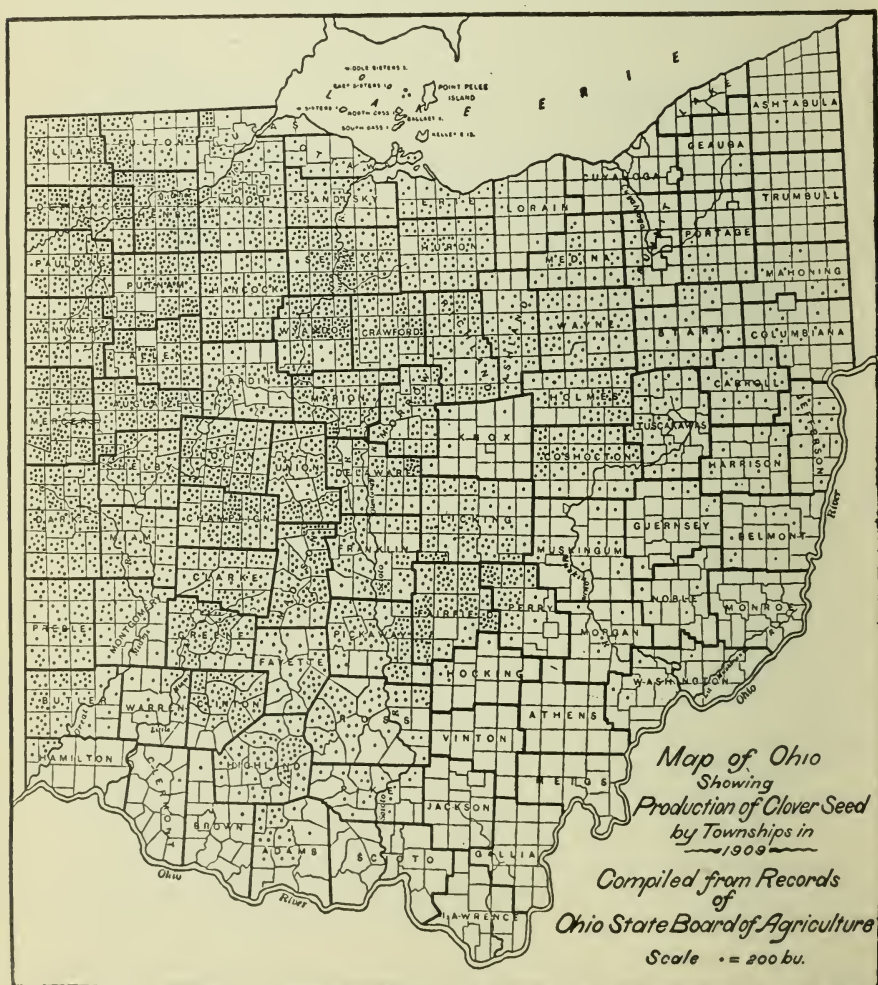


follow it successfully. When they have done this they will have formed a center of production. The more successful the method the more extensive this center of production will become.

In order to be able to find more quickly these centers of production of the various crops and farm products, the Experiment Station has prepared a number of maps on which are plotted graphically the agricultural statistics which are gathered by the township assessors, compiled by the county auditors and then turned over to the Secretary of the State Board of Agriculture. This opportunity is taken to thank the State Board of Agriculture for permission to prepare these maps from its records.

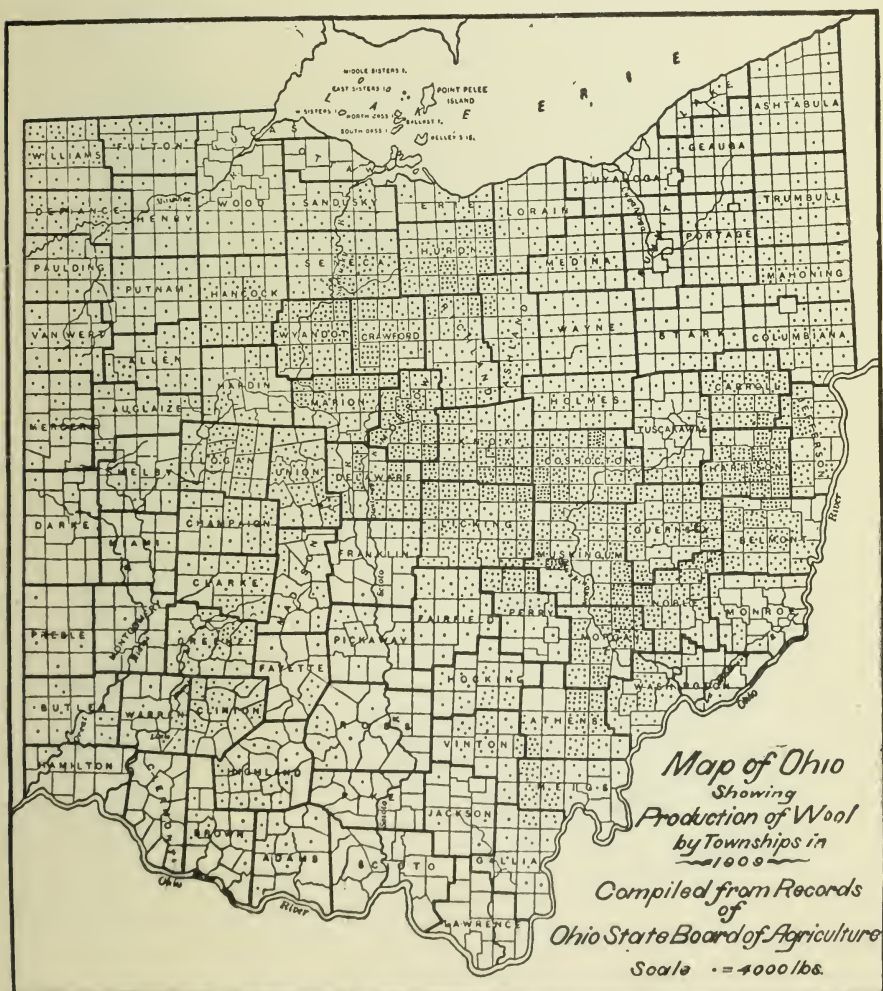


On the following pages are shown a few of these maps. In examining them it will be observed that each dot on the map represents a given number of pounds, bushels, gallons, tons, acres or individuals that were reported for the township on the map of which the dots are placed and that the greater the number of dots in the map of any township the greater the reported production of that township of the product in mind. On the other hand, it must be remembered that the entire absence of dots from the map of any township does not indicate that none of the crop was produced in that township, but that not enough of it was reported to entitle it to

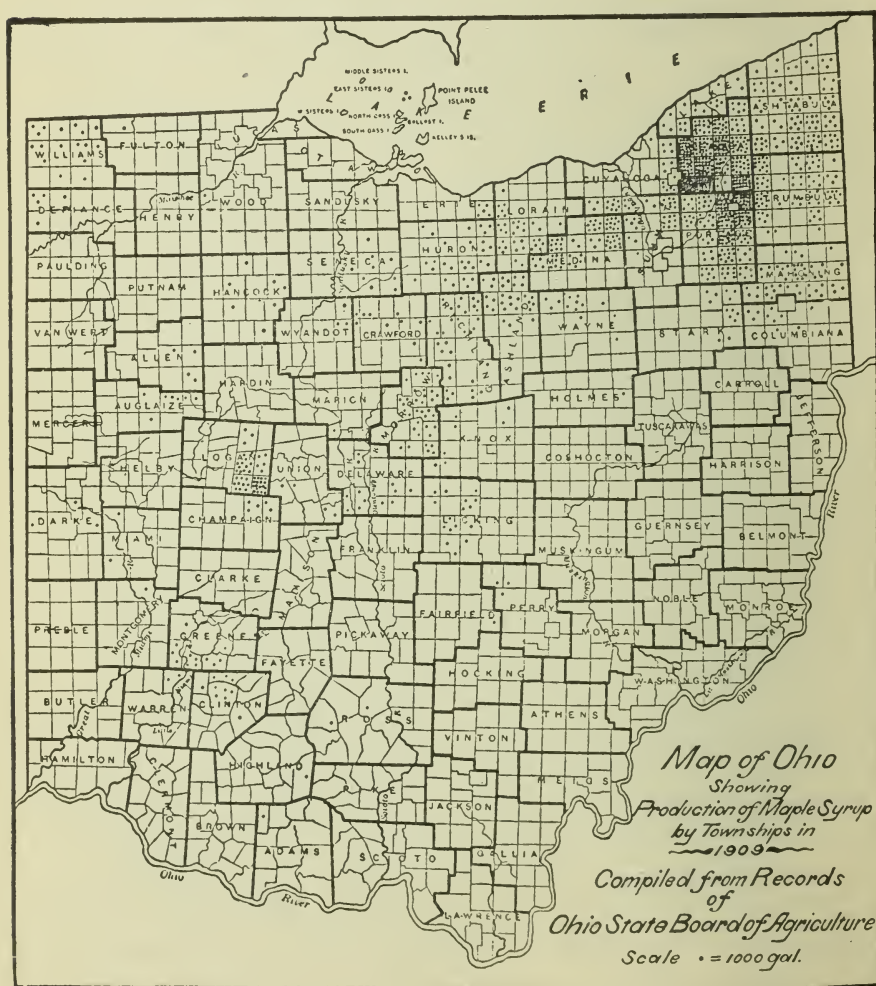


a single dot. For instance, unless the report of a township shows more than 5,000 bushels of corn it would have no dot on the corn map. It should also be remembered that the maps in this circular were prepared from statistics gathered by the assessors in the spring of 1909 and represent in most cases 1908 production.

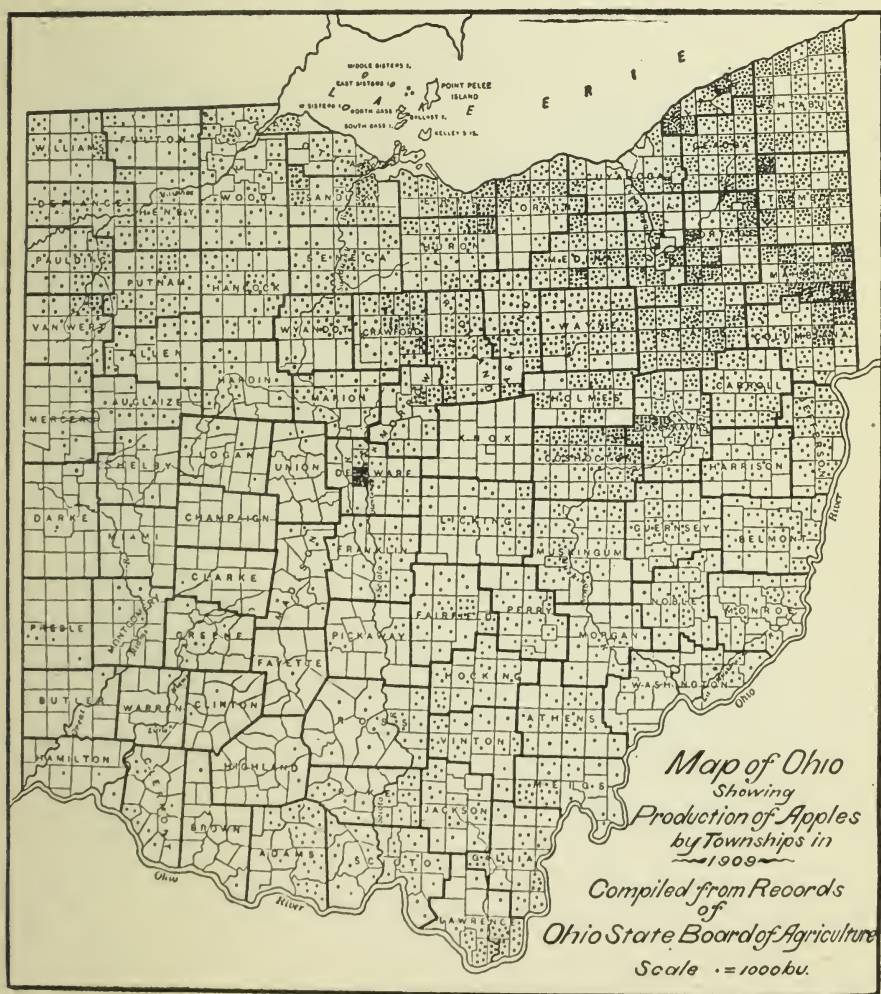
By an examination of these maps, what is meant by a center of production will become clear. For instance, the major center of production of tobacco is in parts of Darke, Miami, Preble, Montgomery and Warren counties. The minor centers are in Adams, Gallia, Noble and Belmont, Medina and Wayne counties. The map of oat production will show that according to these statistics the



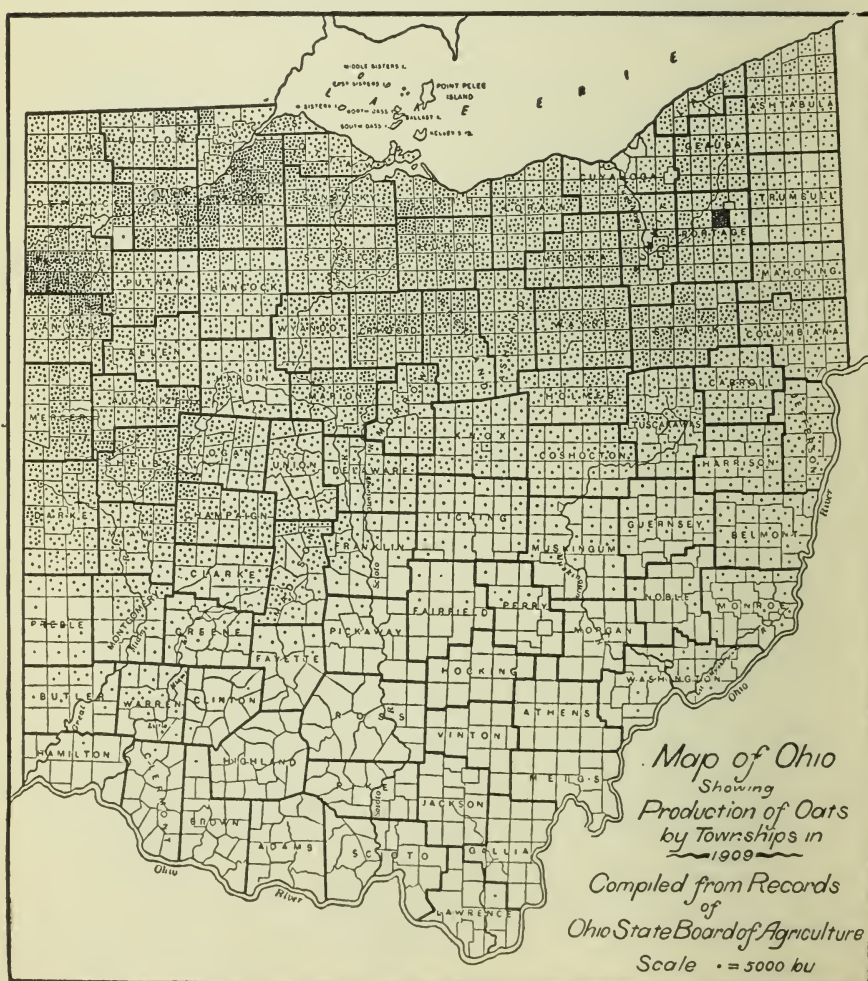
major part of the crop for the year mapped was produced pretty generally throughout the northern part of the State, with Paulding county as perhaps the greatest center of production. In Champaign and Logan counties on the alfalfa map will be seen a center which doubtless spread from a single pioneer alfalfa grower, other centers in connection with this crop having sprung up at a later date in other parts of the State. The center of apple production in the southern townships of Lawrence county illustrates what may be accomplished in the hills by a demonstration of a good method of apple growing.



A comparison of the maps for the year 1909 with those for the previous year has proven very interesting. With such crops as maple syrup, for instance, the centers of production have remained the same. With some other crops the variation has been slight, while in the case of clover seed, for instance, the maps for the two years are radically different. The study has not progressed far enough to produce certain evidence of the spreading of the centers of production of any of the newer crops or of the contracting of the centers of production of any of the crops. It will be manifest, however, that such spreading or contracting will become evident on these maps as soon as it does appear in the statistics.

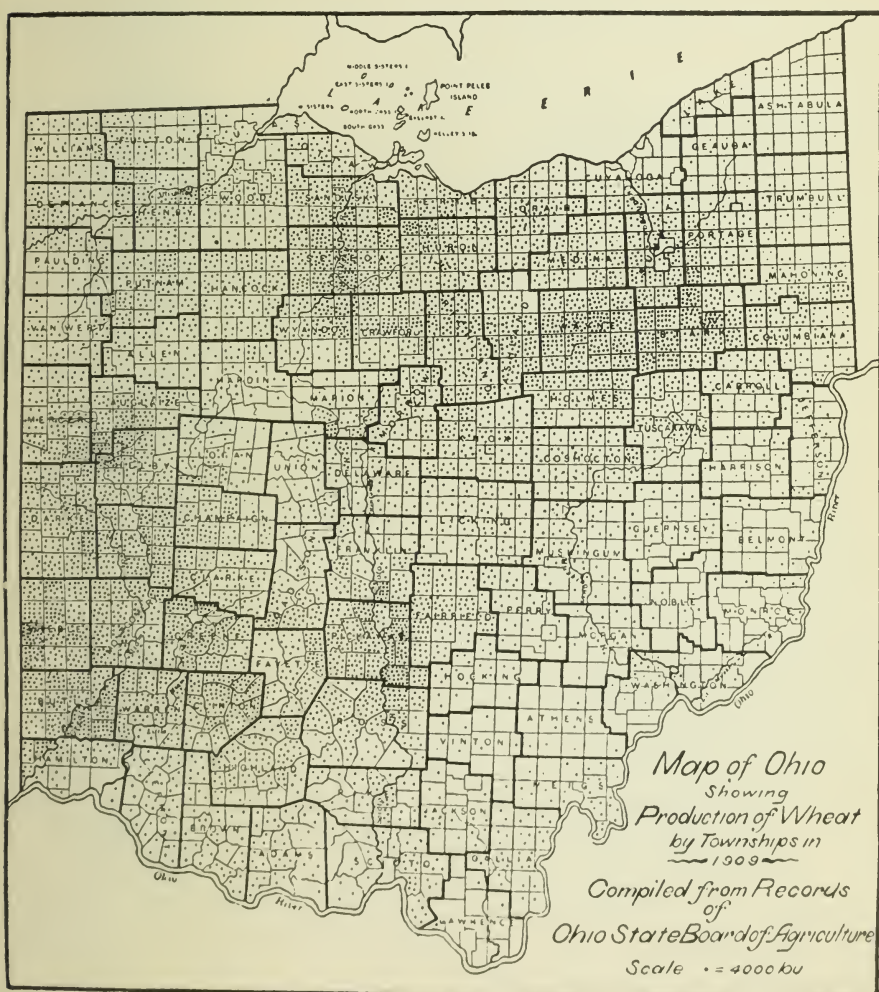


Even a hasty examination of these few sample maps will probably develop some surprises. Many will wonder, for instance, why the counties in the so-called wheat area of northern Ohio show no greater production of wheat than do some counties in south-western Ohio; but if they were to see the maps showing the number of acres sown to wheat in the two areas, they would then realize that in the latter area the shorter rotation causes a greater acreage to be sown to wheat and a consequent greater total production of this crop per square mile in spite of the lower yield per acre. A great many people are disposed to question the accuracy of all statistics. It is



believed, however, that any thoughtful student of Ohio's production will finally decide that while minor errors in the statistics from which these maps were plotted may exist, they are not sufficient to affect seriously their value for use in comparisons of this kind.

The more careful observer may and probably will discover manifest errors which, in all probability, unfortunately do exist. For instance, for one of the very good townships of the State no report whatever regarding any crop has been made. In some other cases the indications have been very plain that in copying, the decimal points have not been placed where they belonged. In plot-



ting the maps for the year 1908, the effort was made to rectify these errors, so far as possible, but after some consideration it was decided to plot the 1909 figures just as they were returned, with the thought that if they were presented to the public in that way and especial attention was called to the value of such statistics, greater accuracy might be secured in the future. And since the year 1910 is census year, it was thought that this would be a very good year in which to make the start. It is well known that the United States Bureau of Census is making a special effort to have the agricultural statistics which they gather this year much more



accurate than ever before. Why should not Ohio make an equal effort? And again, why should not Ohio's statistics for the year 1910 be as accurate as those of the Bureau of Census? The same people give information to both the assessors and the Census enumerators, and certainly the former should be just as accurate as are the latter.

Ordinarily, the Census returns are compiled by county only; whereas, as will be manifest from these maps, it is very important that the statistics shall be compiled by township. On almost every map striking variations within the boundaries of a number of counties, will be evident. In considering the possibility of using the

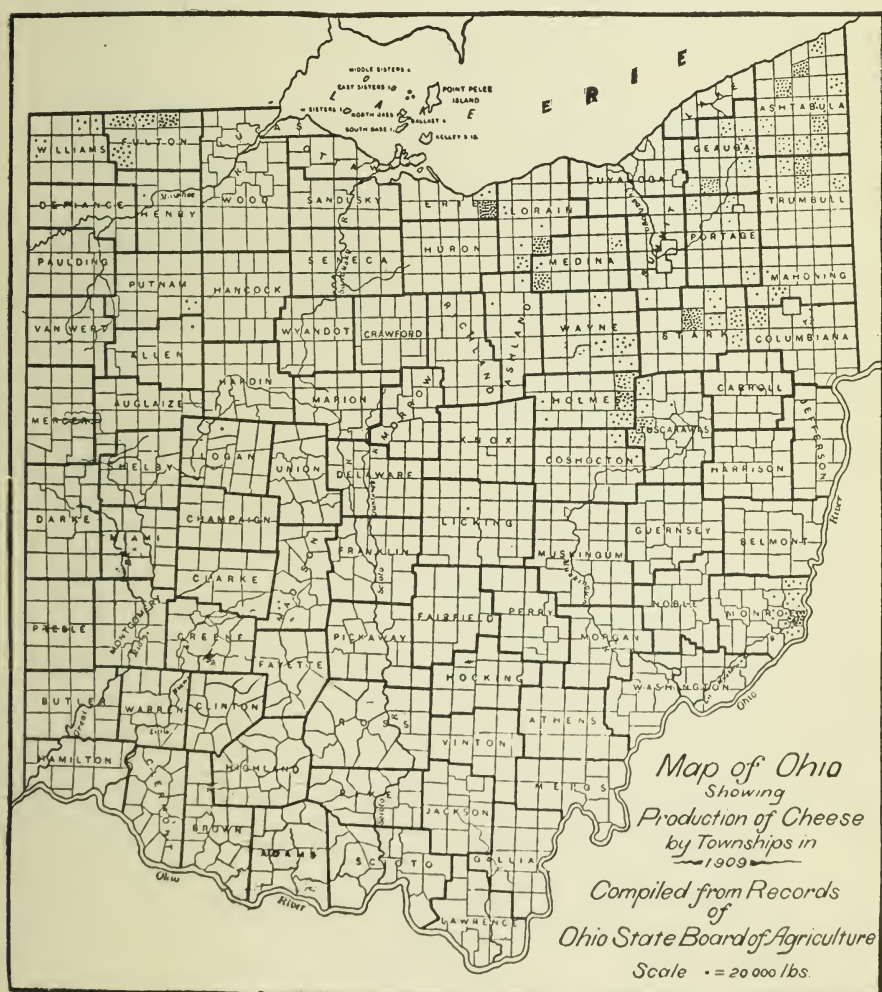


Census report, the Director of the Census was asked to make an estimate of the cost of compiling their statistics by township instead of by county. He accordingly had tabulated by township on their new tabulating machines the 1900 records of acreage and yield of the corn crop of Delaware county and, on the basis of time used for that tabulation, estimated that for the entire state it would cost extra for this township tabulation of the 1910 corn crop figures from \$125 to \$175. For some crops the tabulation would not cost so much but for others it might cost still more. He also advised that in order for them to be able to do it even at these prices, he must know of Ohio's desire before they take up the regular work.



In the light of these figures and in view of the fact that yearly statistics are many-fold more valuable to Ohio than are decade statistics, is it not worth while for every auditor and every assessor in the State to undertake to have these Ohio statistics just as complete and just as accurate as the best? Certainly, if it is not worth doing in the best possible manner, it is not worth doing at all.

If the officers above mentioned will undertake to do their part the Experiment Station, on the other hand, will undertake to present the work to the people in connection with its Farm Management work, and through the still greater work, the Agricultural Survey of the State, which it hopes to undertake in the near future.



When the Ohio and Census statistics are both available, the Experiment Station proposes to compare them county by county and, if funds are available, to make arrangements with the Bureau of Census to tabulate their statistics of a single crop by township, in order that the comparison may be carried still further into detail. In letters of March 15th and 22d, 1910, the Director of the Census proposes cooperation with Ohio in learning wherein lie the causes of any variation which may exist between the Census and State statistics for this year. The auditor of one county has offered to assist in this comparison by making available for this purpose the original returns of the assessors of his county. Others will



doubtless be glad to do so likewise. There is no question but that all the auditors of the State have the welfare of the State at heart, and will do all in their power to promote it. The same could doubtless be said of the assessors.

The Experiment Station would therefore make a special appeal to the county auditors of Ohio to bring this matter to the attention of their assessors, in the hope that errors on their part may be avoided this year, and then to use the utmost care in making their own tabulations in order that when the work is complete we may all be proud of our State statistics.



Ohio Agricultural Experiment Station.

CIRCULAR No. 101

WOOSTER, OHIO, MAY 12, 1910

ILLUSTRATIVE EXHIBITS AT STATE AND COUNTY FAIRS

BY L. H. GODDARD AND W. A. LLOYD

A rational system of agriculture
cannot be founded without the
application of scientific principles.
—Leibig.



THE COUNTY FAIR: The social
climax of the rural year. It should
typify as well the progressive
agricultural spirit of the com-
munity.

FAIRS TO BE VISITED IN 1910

Exhibit will be open to the public on Wednesday and Thursday and
until noon Friday of each week.

COUNTY	TOWN	WEEK OF
Allen	Lima	September 5-10
Ashtabula	Jefferson	August 15-20
Athens	Athens	September 26-October 1
Auglaize	Wapakoneta	August 29-September 3
Belmont	St. Clairsville	September 19-24
Champaign	Urbana	August 22-27
Franklin	Ohio State Fair	September 5-10
Coshocton	Coshocton	October 10-15
Greene	Xenia	August 8-13
Guernsey	Washington	September 26-October 1
Hamilton	Carthage	August 15-20
Hancock	Findlay	September 12-17
Hardin	Kenton	August 22-27
Harrison	Cadiz	October 3-8
Lorain	Wellington	August 22-27
Lucas	Toledo	September 12-17
Marion	Marion	September 26-October 1
Medina	Medina	August 29-September 3
Mercer	Celina	August 15-20
Miami	Troy	September 19-24
Morrow	Mt. Gilead	October 3-8
Muskingum	Zanesville	September 12-17
Putnam	Ottawa	October 3-8
Scioto	Portsmouth	August 29-September 3
Seneca	Tiffin	September 5-10
Washington	Marietta	September 19-24

ILLUSTRATIVE EXHIBITS AT STATE AND COUNTY FAIRS



THE first agricultural fair in America was held at Pittsfield, Berkshire County, Massachusetts, in the year 1810. Elkanah Watson, a retired merchant from Albany, New York, instituted the fair and kept it going for a number of years. In 1815 Mr. Watson returned to Albany and organized the Albany Agricultural Society. In 1819 through his influence the New York legislature appropriated \$10,000 for promoting agriculture, and this appropriation was renewed annually for six years. In 1837 the State Agricultural Society was or-

ganized. The other states very rapidly followed the leadership of New York in the organization of Departments of Agriculture and Agricultural Societies.

The first bill to organize a State Board of Agriculture in Ohio was introduced by Hon. Almer Hegler, of Fayette County, in 1838. The Board was finally organized in 1844 and the first State Fair was held at Cincinnati in 1850. For a number of years the fair was rotated among different cities in the state: Cincinnati, Cleveland, Dayton, Newark, Sandusky, Zanesville, Toledo, Springfield and Mansfield each having one or more exhibitions. In 1874 it was located permanently at Columbus.

The early fairs were primarily agricultural, with an incidental commercial aspect. In the years following the Civil War many of the fairs became largely amusement aggregations with agriculture an incident or in some cases only a name. With the birth of the Agricultural College and Experiment Station there began a change in the character of the County Fair. The indirect influence of these institutions was first felt through the increased interest, stimulated by them, in improved livestock and better farm products. From this time the fairs began to return rather slowly to their original purpose. Some of the Colleges and Stations early saw an opportunity for educational and demonstrational exhibits at the fairs. As early as 1877 the Ohio College of Agriculture made exhibits at the State Fair. Soon after the organization of the Ohio Experiment Station in 1882 this work was taken up by it and has been continued almost every year since.

THE EARLY EXHIBITS OF THE EXPERIMENT STATION

The first exhibit made by the Experiment Station was at the Cotton States Exposition at New Orleans in 1883. This consisted of a collection of grains and grasses. The Station was represented at the Chicago World's Fair in 1893 by an exhibit in connection with the Office of Experiment Stations, United States Department of Agriculture. It was also represented at the Paris Exposition in 1900 in a similar manner.

The early exhibits at the Ohio State Fair consisted of samples of grain in the straw and in glass jars, with a small variety display of potatoes. The first time the Station made an exhibit at a county fair was at Wooster on September 22 and 23, 1891, after it had been decided to remove the Station to Wayne County. The exhibit was made under a tent about 12 by 20 feet in size. The same exhibit was made at a street fair at Doylestown on September 29th and 30th of the same year. An exhibit of much the same character was made at Orrville, October 11, 1893. With the growth of the Station and the addition of new Departments, the exhibit was somewhat enlarged, though it kept the same general character until 1905.

COUNTY EXHIBITS

The first visit to a county other than the one in which the Station is located was made when the exhibit was taken to the Stark County Fair at Canton, September, 1897. This was repeated in 1898. An exhibit was made at the Wayne County Fair in 1899 and again in 1902. Each year since that time until 1908 the Station has been represented in some way at the local fair. In 1909 it was decided that since the citizens of Wayne County had in the Station itself a permanent exhibit much more comprehensive in character than any that could be made at a county fair, and that, inasmuch as a most cordial invitation is always extended to any who care to visit the offices or fields of the Station, a greater duty to make county fair exhibits exists towards the counties which are more remote from the Station and whose access to it is not so easy. The Station made a small exhibit at the Preble County Fair at Eaton in 1904.

Beginning with 1905 the general policy of making exhibits at the county fairs was inaugurated. To help in paying transportation charges and other expenses incidental to moving and installing exhibits, \$30 was charged each agricultural society securing the exhibit. In this year the Station made exhibits at seven fairs, located in the counties of Summit, Cuyahoga, Fulton, Wood, Franklin, Clinton and Hamilton. The display was now somewhat enlarged. Features

showing the losses from waste of manure and gain from the application of fertilizers and manure under different methods of treatment were added. The illustration given below shows the exhibit as displayed at the Hamilton County Fair at Oakley in August, 1905. It illustrates fairly well the character and extent of the exhibits up to and including 1907. In 1906 the exhibit was further enlarged and was sent out under special shipping arrangements. Nine fairs were visited this year: the State, Preble, Richland, Geauga, Trumbull, Meigs, Putnam, Fairfield and Huron counties. In 1907 seven fairs were visited. Besides the State Fair an exhibit was made in Geauga, Trumbull, Richland, Putnam, Mercer and Huron counties.



The exhibit at the Hamilton County Fair (Oakley) 1905.

THE WORK SYSTEMATIZED

In 1908 the exhibit was considerably enlarged and made representative of the entire work of the Station. Eight counties were visited: Mercer, Darke, Franklin (State), Trumbull, Shelby, Butler, Stark and Wyandot.

Up to and including 1908 the matter of assignment of fairs to which the exhibit was to be sent had been governed entirely by priority of application. This had resulted in some counties receiving the exhibit year after year, while others failed to secure it at all because of delayed applications. It had also caused very long trips between fairs, and consequently the railroad transportation had

become a serious problem. Indeed, in 1907 in two cases the car containing the exhibit failed to arrive in time for it to be installed at the fair. To reach the eight fairs visited in 1908, it was necessary to cross and recross the state five times, the total distance traveled being more than 1600 miles. Moreover, applications for the exhibit were coming in from all parts of the state. Some system was therefore necessary to avoid similar if not greater difficulties in future years. To accomplish this end the Experiment Station proposed to the Fair Manager's Association a plan of cooperation in the matter of making assignments of fairs to which the exhibit should be sent. This plan was agreed to by the Association and a committee was appointed which took up the consideration of the applications for the exhibit for 1909. It was first decided by the committee that in selecting the fairs, no county should be included to which an exhibit had been sent in previous years.

To the earnestness and enthusiasm of this committee is largely due the increased appropriation made by the legislature for fair exhibit purposes, which appropriation made it possible to send out two exhibits in 1909. The saving in car mileage that came as a result of the work of this committee is clearly shown by a comparison of the mileage of the last two years.

In 1908, fairs visited 8, miles traveled 1604, miles per fair 200.

In 1909, fairs visited 20, miles traveled 2108, miles per fair 105.

Every detail of the route to be covered in 1909, and to a large extent in 1908, was worked out with the railroads months in advance, and every facility for the prompt handling of the cars containing the exhibit was made available by them. But for this kindness on their part disappointments by failure to arrive in time for installation of the exhibit, as in 1907, would probably have arisen in 1908.

Another matter, which had caused serious embarrassment in previous years, was the inadequacy of the space available for the exhibit at some of the fairs. Insufficient table room and wall space to properly display the exhibit, poor light and bad location on the fair grounds, had in many cases tended very greatly to lessen the influence of the exhibit. To overcome the inconvenience caused by this lack of systematic arrangement, every fair to which the exhibit was sent in 1908 was visited in advance by a representative of the Station and definite space arranged for. In arranging for the fairs to be covered in 1909, in connection with this advance work, a formal Memorandum of Understanding was signed with each Agricultural Society, in which was stated just what was expected of the Society and what would be done by the Experiment Station.

DESCRIPTION OF THE COUNTY EXHIBITS

The exhibits as sent out by the Station are purely illustrative in character. No competitive entries are made; no attempt is made to show fine products. The idea back of every feature of the exhibit is to show the result of an experiment. Only well established truths are shown; in most cases the average result of several years' work is given. Moreover, it is not such a display as can be seen profitably at a hasty glance. While each feature is so arranged as to make it a graphic presentation of some great truth, its chief value is in the many questions it suggests. The enthusiastic reception accorded the exhibit by farmers everywhere is one of the most encouraging signs of agricultural development.



These fellows help solve the problem of soil fertility on a well managed farm.

SOIL FERTILITY

The problem of restoration and conservation of soil fertility is one that arouses most intense interest and is of fundamental importance. It applies alike to the rich, fertile plains of the West, the thinner, more refractory soil of the Northeast and the steep, non-glaciated hillsides of the Southeast. Decreased yield, failure of clover, and barren hillsides have all sounded the alarm of soil depletion. It was not strange, therefore, that around the exhibit of the Department of Soils there was always to be found a group of interested men.

This exhibit told in a graphic way the increased yield from application of manure under different methods of treatment in a three-year rotation of corn, wheat and clover. Average results of twelve years' work were shown. This was done by means of a number of imitation bales of hay and sacks of corn and wheat so arranged as to show the exact amount of increase from manured plots over unfertilized plots. Results from the use of a complete commercial fertilizer, open yard manure, stall manure and stall manure treated with forty pounds acid phosphate per ton of manure, were shown. Large

cards giving complete details of the results of the experiment and the net value per acre of the increase in each case were so arranged as to make the experiment easily understood. A large banner with the legend "Will You Sell Manure at \$5.00 per Ton?" was very successful in attracting attention to this exhibit. It was shown by this illustration that results in excess of this amount have been obtained at the Station farm.

VALUE OF DIFFERENT KINDS OF MANURE

In close proximity to the above exhibit was that of the Department of Chemistry. In this was shown the fertilizing value of manure from the various farm animals. This was done by means of a number of glass tubes in which were the proportionate amounts of nitrogen, phosphoric acid and potash contained in the manure of the horse, cow, sheep and hog. In a similar way was shown the amount of lime, phosphorus, potassium and nitrogen removed by an average yield of corn, wheat, oats, potatoes, timothy hay, soybeans and clover.

FARM CROP EXHIBIT

In the exhibit of the Department of Agronomy there were shown sixty varieties of wheat and oats in the straw; samples of rye, emmer, barley and winter oats; a number of varieties of millet; the native American grasses—timothy, red top, blue grass and orchard grass, and the foreign grasses—rye grass, tall oat grass, brome grass and meadow fescue. There were also a number of the common legumes, including red, alsike and mammoth clover, alfalfa, soybeans, cowpeas, lupines, beggar weed, etc. The effect of early and late, and thick and thin seeding of oats and the average yield of twenty varieties of this crop were shown.

The corn breeding work was illustrated by showing several years' results with individual ears in ear-to-the-row work; one end of a rack showing by means of the height of the corn in glass tubes the yield of individual ears in the first year of the ear-to-the-row work, while in the other end was shown the results of crossing high-yielding ears, of inbreeding and of crossing low-yielding ears in multiplying plots. This department also had a number of interesting bromide enlargements of photographs showing alfalfa breeding work.



The effect of manure and fertilizer on farm crops is shown in this exhibit



A few bad weeds shown by the Department of Botany.



WEEDS have been described as "plants out of place", and there are a large number of such plants which have long been considered as out of place on well-kept farms. The number of these seems to be constantly receiving additions from one source or another, so that the vigilant farmer must be ever on the aggressive in the long-continued warfare against these meddlesome enemies. Not only does weed growth be-

speak untidiness in husbandry, but it also consumes moisture and plant food which is needed by the more valuable plants. For these reasons the large display of pressed and mounted weeds shown by the Department of Botany was always a source of much interest. The broad leaf, the buckhorn, and the bracted plantain, the ox-eye daisy, wild carrot, yarrow, horse nettle, Canada thistle, mustard and many other dangerous weeds were shown. The Weed Manual describing the weeds and giving methods of combating them was much in demand. There were also exhibits showing plant diseases:—wheat scab, anthracnose, early and late potato blight, etc. At some fairs quite a large number of weeds were brought in by the farmers for identification. In many cases these could be found among the specimens shown; in others they were identified by some of the attendants, while in still other cases specimens were sent to the Experiment Station, by which the identification was made and sent to the inquirer. The intense interest everywhere manifested by the boys and girls in this exhibit, and in the butterflies, moths, bugs and insects of the Department of Entomology, indicates the readiness and willingness, so far as the children are concerned, to learn something of the common, everyday things of farm life.

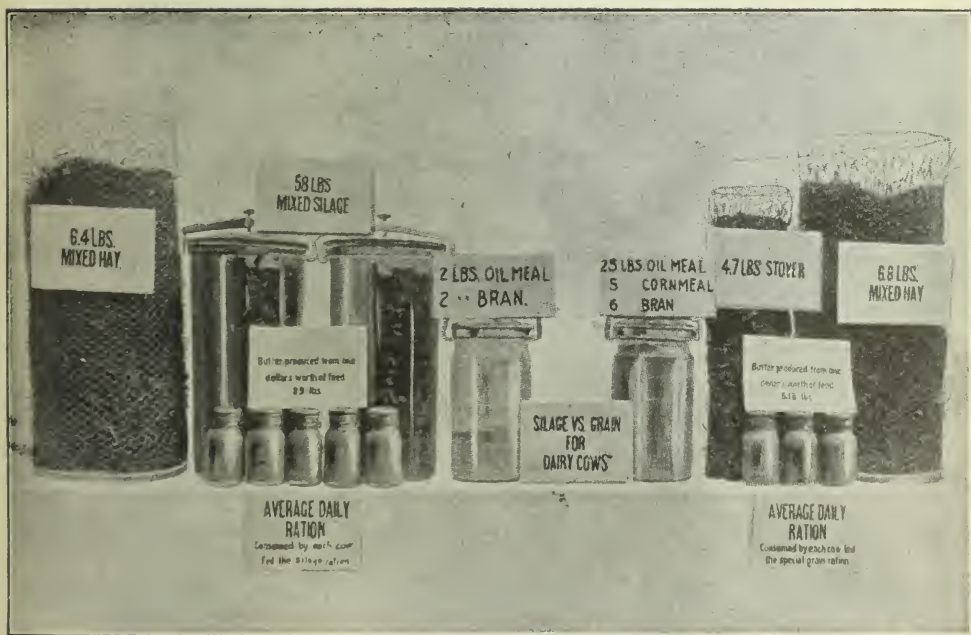
Another feature of the work of the Department of Botany was an exhibit showing some of the more common adulterants of clover and grass seeds. While the United States Department of Agriculture, the Agricultural College, or the Experiment Station will gladly make purity tests of any of the farm seeds, it is advisable for the farmer to know for himself the more common adulterants. Peneath magnifying glasses were shown the dodder with the alfalfa seed, the plantain in the clover, and many others that the intelligent observer would afterwards recognize should they occur in commercial seed.



A bunch of money-makers.

ECONOMICAL FEEDING OF LIVE STOCK

Except in a very limited area of the state, livestock is an important factor in the farm equation. The intelligent use of feeds in a way to make the greatest and most economical gains will go a long way in putting the balance on the right side of the farm ledger. Among the features of the display of the Department of Animal Husbandry was an exhibit showing the value of corn in comparison with oats as a feed for horses doing regular daily work. This was shown by means of representative daily rations of corn and oats with mixed hay. In the experiment illustrated, one horse of each team in the test was fed a corn and one an oat ration, careful observations being made of each horse as to weight, spirit, endurance, etc. Rations for fattening range lambs were likewise shown. There was also an exhibit showing the value of silage in comparison with grain for dairy rations. One ration consisted of corn silage and clover hay with a small amount of grain; in the other the silage was displaced by corn meal, bran and oil meal. The amount of butter produced by one dollar's worth of these rations was illustrated by means of a representative exhibit showing the respective amounts of butter for the two rations. There was also an illustration of a pig-feeding experiment, showing the comparative value of corn, corn and middlings, corn and tankage and corn and skim milk as a ration for fattening swine. The value of these rations was exhibited so as to show the amount of each of the above feeds used for one day's feeding and the necessary amount for one pound gain. The daily gain per pig was shown by proportionate amounts of bacon.





THERE has arisen a host of insect and fungous enemies to hinder and destroy every plant, every grass and grain and fruit and flower that man has subjugated and improved and made to minister to his sense of the useful and beautiful. The slaughter of the birds that once held these pests in check has left science to find artificial means of combating them. Not all insects, however, are harmful. In the exhibit of the Department of Entomology many specimens of both the beneficial and the injurious were shown. Not only were there beautiful mounted specimens of the adult insects, but also the life history of many of them was illustrated: the caterpillar, the chrysalis and the pupa in all stages of development. There were also exhibits showing the effect of the various scab and fungous diseases on fruit and forest trees; samples of various spray mixtures with the directions for application; the different nozzles used in spraying; a number of photographs illustrating the work in orchard, field and garden; small microscopes beneath which were mounted a number of common insects, and a large map of Ohio showing distribution of wheat joint worm in 1908 and 1909. A number of the best books on the subject, suitable for popular use, were available at all times for examination.

FORESTRY EXHIBIT

Ohio contains much land that nature probably intended should remain in perpetual forest. Much of the original growth was wasted, and nature's attempt to reforest has been arrested. Bleak and barren fields, gullied and washed hillsides, stand as witnesses of the fearful punishment that is exacted for this misappropriation of the gifts of the Creator. In every part of the state the available supply of timber for building material, for fuel and for posts is rapidly diminishing. To supply these farm wants and the increasing demands for railway cross-ties, telephone, telegraph and traction line poles, and to provide lumber for the future, makes the subject of forestry one of great practical and economic interest throughout the state.

The Forestry Department was represented by sections of catalpa trees showing total growth on one-eighth of an acre in nine years. There was also shown an entire catalpa tree nine years old, 36 ft. high and 16 inches in circumference. The effect of weed trees in the forest was shown by a block from a worthless beech with cross-sections from each tree of the scanty and comparatively valueless growth



Showing representative baskets of sprayed and unsprayed fruit from a cooperative orchard in Washington County.

found under its shade, in comparison with cross-sections from each tree growing on the same area immediately adjoining. Bromide enlargements of photographs showing forest conditions formed an interesting part of the display of this Department.

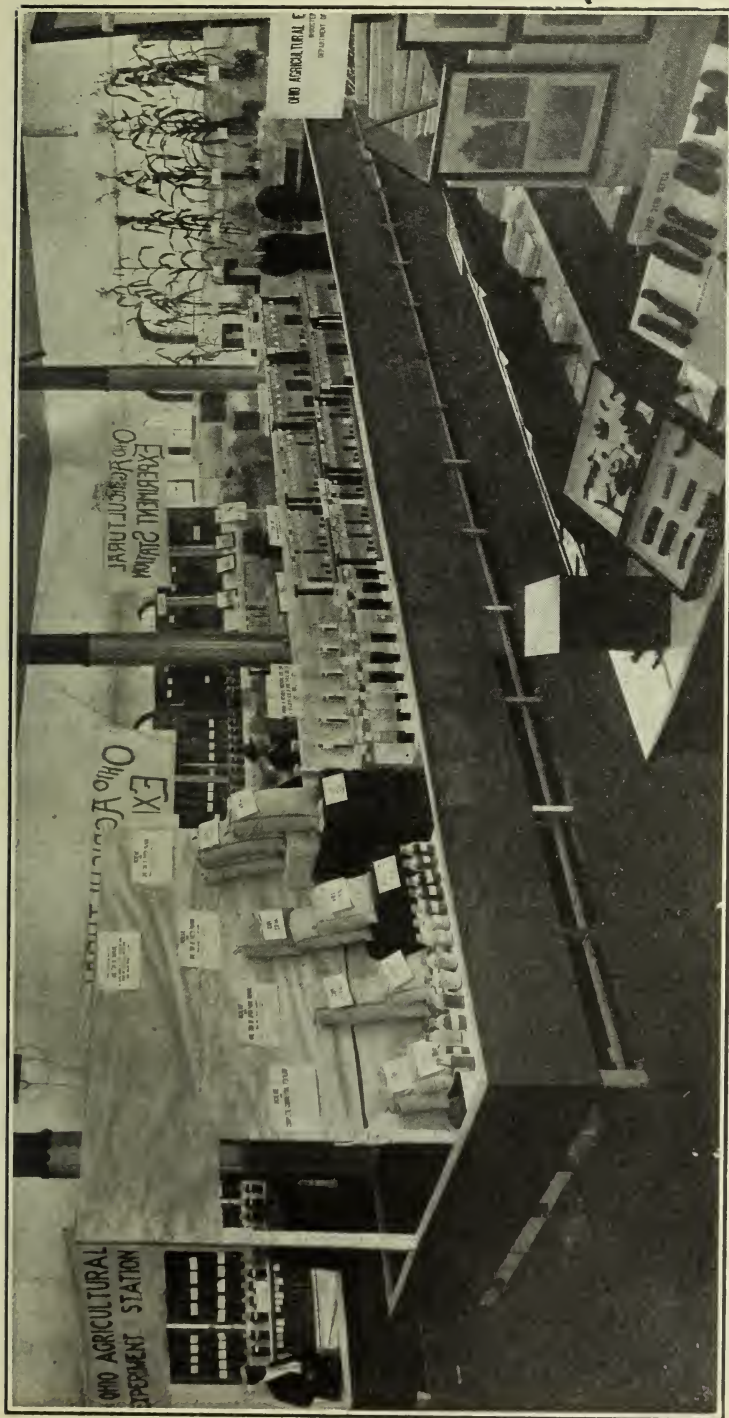
EXHIBIT SHOWING EFFECT OF SPRAYING

Some of the most valuable work of the Station is done in cooperation with farmers throughout the state. An illustration of this work was furnished by the Department of Horticulture. In the spring of 1909 this Department took charge of three orchards in Washington county which for a number of years had failed to produce profitable crops. This is a part of the state which had once grown beautiful fruit. The Station effectively sprayed these orchards throughout the season. The entire products of sprayed and unsprayed trees were shown and the striking differences both in quantity and quality of the sprayed and unsprayed fruit were such as to awaken much interest in scientific spraying of fruit trees.

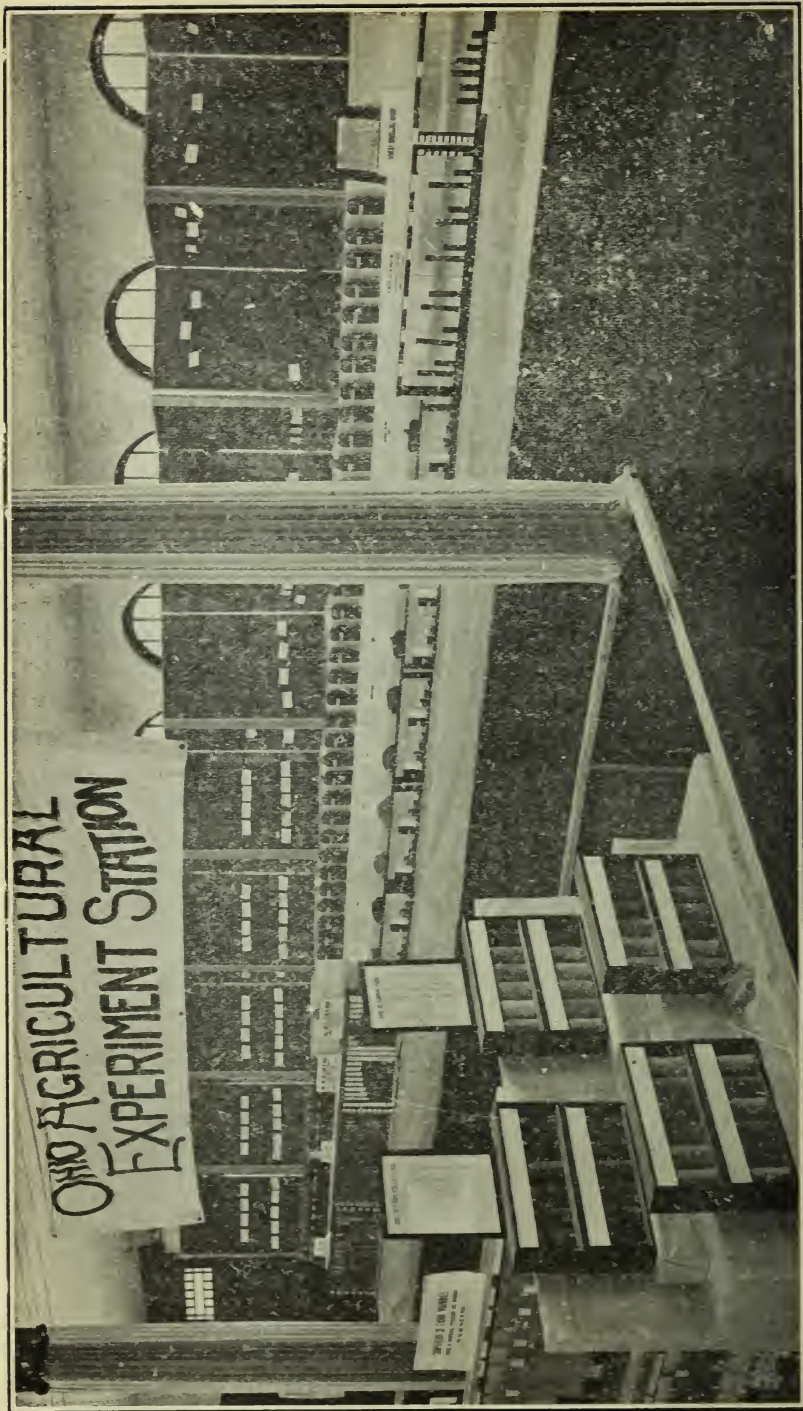


The variety display of apples.

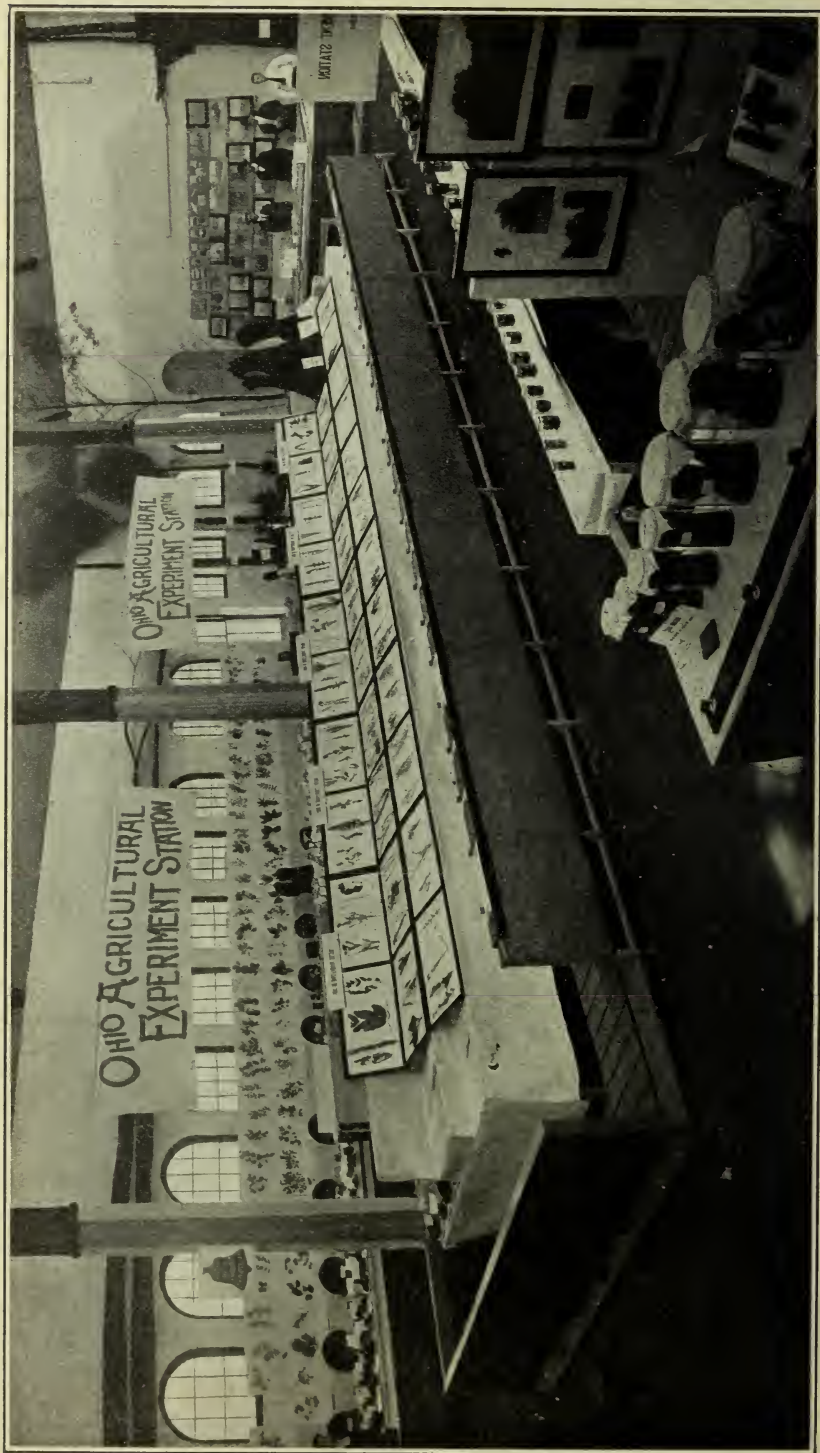
The variety display of apples and potatoes varied somewhat at the different fairs. It excited much favorable comment and was frequently the means of identifying some specimen brought in by a grower. Much interest was also manifested in the exhibit showing the relative value of different fertilizers with potatoes; also in the plant breeding work showing the results obtained from using seed potatoes from high-yielding hills.



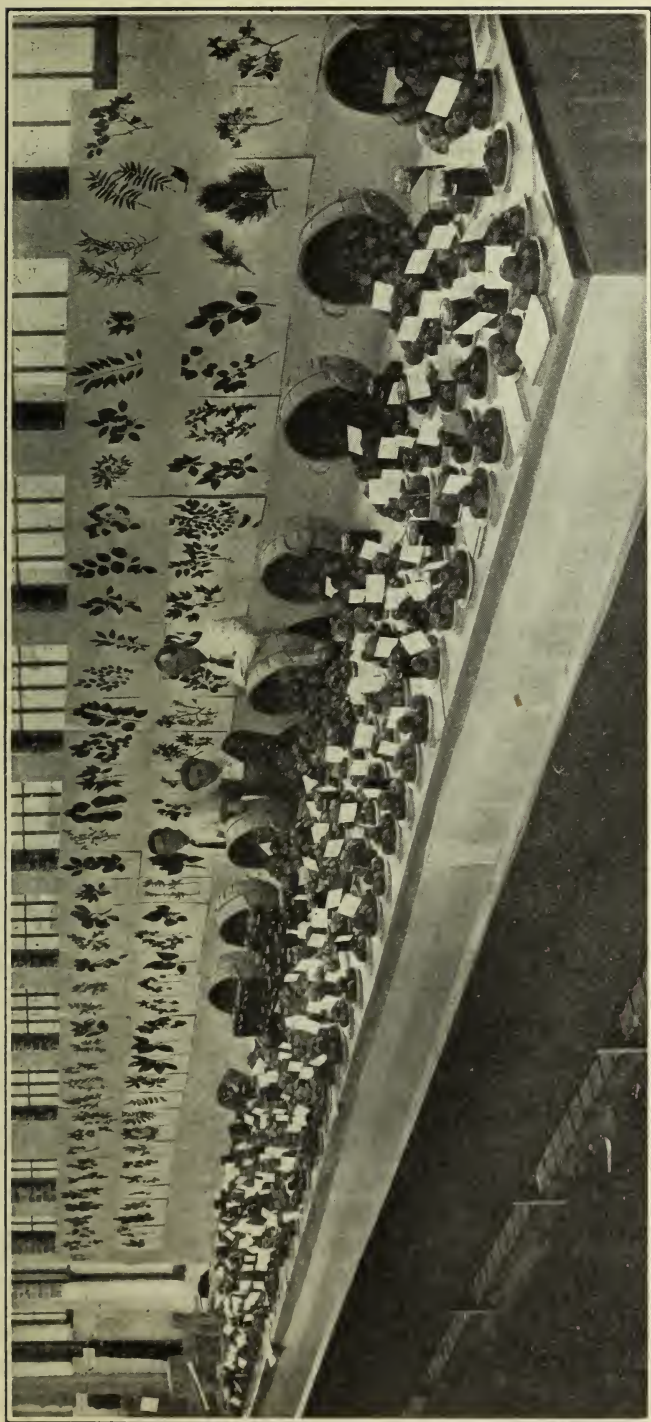
Exhibits of the Departments of Soils and Chemistry at the State Fair.







The Department of Botany at the State Fair.



A part of the exhibits of the Departments of Horticulture and Forestry at the State Fair.

NUTRITIVE VALUE OF FOODS

The exhibit of the Department of Nutrition consisted of representative samples of some of the common foods for both human and animal consumption. The high cost and low nutritive value of some of the common breakfast foods as well as of a number of the commercial stock foods was very effectively shown.

THE STATE FAIR EXHIBIT

The exhibit at the State Fair was of the same general character as those at the county fairs. Some new features were added, though in the main they were amplifications of those made at the county fairs. In addition to the car containing Exhibit No. 2, which was sent to Columbus from the Fayette County Fair, another car was sent from the Station direct. In all there was used more than ten tons of exhibit material. This was installed in the west half of the East Central Building, the new quarters which had been assigned to the Experiment Station by the State Board of Agriculture—the area used for the exhibit measuring seventy by one hundred feet.

SPECIAL EXHIBITS

A few special features of the exhibit at the State Fair not heretofore described under county exhibits, were as follows:

By the Department of Forestry, an exhibition of fence posts made from the various kinds of timber commonly used for this purpose. The posts used in this display had seen actual service and the comparative durability was very effectively shown.

The Department of Chemistry made an exhibit showing the effect of lime on soil humus and formation of available nitrogen (nitrates) and the comparative effects on soil humus of equal amounts of lime (2000 lbs.) applied in the form of burned lime and limestone. The several amounts of humus were represented by jars containing organic matter, and the amounts of the nitrates by small tubes on the sides of the jars.

In another exhibit by this department there was shown the pounds of nitrogen, phosphoric acid, potash and lime in some Ohio soils, as peat soil, black clay loam, red clay loam, Miami clay loam and Miami silt loam. Samples of the soil were displayed in trays properly labeled. The amount and constituents of each soil were represented by different colored materials placed in tubes, using one for each sample of soil.

The Department of Agronomy showed the results of a number of tests with winter wheat, yields of best and poorest individuals, and later results from the best plants as tested in comparison with the original varieties upon tenth-acre plots. There were a number of photographs showing variation, manner of growth,

stiffness of straw, etc., in pure lines of wheat. The effect of thick and thin plantings of corn was shown by sample hills with four years' average yield. A special exhibit showing samples of flour, mill products and loaves of bread from ten varieties of winter wheat was particularly interesting and instructive. There were a number of photos showing varieties and strains of alfalfa descended from single plants, which showed variation as to hardiness, proportion of leaves, manner of growth, etc., also of plants showing effect of inoculation.

The Department of Animal Husbandry made, as it did in 1908, an exhibit of live hogs illustrating a feeding experiment. Two of each of five lots of hogs were shown. The rations tested were as follows:

Lot 1. Cornmeal 1 part, skim milk, approximately 3 parts by weight, in dry lot.

Lot 2. Cornmeal 4 parts, soybean meal, 1 part by weight, in dry lot.

Lot 3. Cornmeal alone, in dry lot.

Lot 4. Cornmeal on mixed pasture (chiefly timothy and bluegrass).

Lot 5. Cornmeal on clover pasture.

Banners were displayed describing the exhibit and cards were distributed giving full details as to the results.

DAILY LECTURES

A lecture room equipped with rostrum and chairs had been provided by the State Board of Agriculture, and during the fair a number of lectures were given by members of the faculty of the College of Agriculture and of the staff of the Experiment Station. This is a feature which, with proper advertising and announcement on the grounds during the fair, is capable of much profitable development.

EXPLANATION OF THE EXHIBIT AT THE COUNTY FAIRS

The following gentlemen, members of the force of Farmers' Institute Speakers or prominent in agricultural work in the state, were secured by the Station to assist in the explanation of the exhibit: Mr. Cary W. Montgomery, of Newark, Mr. Horatio Markley, of Mt. Gilead, Mr. J. S. Brigham, of Bowling Green, Mr. Jno. T. Brown, of Mechanicsburg, Mr. C. R. Wagner, of Arlington and Mr. C. W. Waid, of New Carlisle. Several members of the scientific staff of the Station, including Director C. E. Thorne, were present for a short time at some of the fairs. No attempt was made by those accompanying the exhibit to give general advice concerning farm problems except so far as they were covered by results of actual ex-

periment work conducted at the Station. Many questions were referred direct to the heads of Departments for specific reply by letter. This has been found to be a good method of bringing the farmers into closer relation with the Station.

A member of the staff of the Experiment Station was in charge of the exhibits at each county fair, as follows:

Mr. G. T. Abbott—Greene, Clark, Hardin, Auglaize, Defiance and Brown.

Mr. M. O. Bugby—Erie, Sandusky and Wood.

Mr. W. M. Cook—Montgomery and Logan.

Mr. W. A. Lloyd—Pike, Ross, Fayette, Van Wert, Knox, Warren Coshocton and Tuscarawas.

Exhibit No. 1 was accompanied throughout the season by Mr. H. C. Lewis, of Zanesville, as advance agent and Exhibit No. 2 by Mr. H. M. Dixon, of the Experiment Station, in the same capacity.

Almost uniform success attended the exhibits throughout the season. This success was largely attributable to the following causes:

1. The preparedness, uniform courtesy and readiness to assist, everywhere manifested by fair officials.

2. The splendid service given by railroads.

3. The excellent work done by the various gentlemen who assisted in the explanation of the exhibit.



4. The generous and friendly attitude of the rural press, which was manifest both previous to and during the progress of the fairs.

If any antagonism or carping criticism exists toward the Station it was not manifest at the fairs. The reception was everywhere cordial and the desire to cooperate abundantly manifest. Many farmers said the exhibit was all that brought them to the fair. Many who spent several hours in the exhibit one day would return the next with one or more neighbors who had come to the fair as a result of their enthusiasm. Every fair developed good missionaries who "went out" and "brought in" others and who did good work in explaining features of the exhibit which most appealed to them.

A REGISTER FOR THOSE DESIRING BULLETINS

A book with the invitation "If Interested in the Exhibit, Please Register," was kept at each of the fairs. The total registration at all the county fairs amounted to 5,115 and at the State Fair 2,640. Ninety-seven percent of those registering at the county fairs were adults seemingly thoroughly interested in the exhibit, while probably 30 percent of those registering at the State Fair were people who were in no way interested in the exhibit, simply registering as a matter of curiosity. Since the fairs, an opportunity to receive the bulletins and publications of the Station has been given to each of those registering. As a result of this work there have been added 950 new names to the list of those wishing bulletins and publications from the Station. The following table gives the attendance and the number registering at the different fairs.

CARDS AND BULLETINS

Cards describing the various experiments were placed conveniently accessible to all who wished them. A supply of many of the bulletins of the Station was carried with the exhibit and distributed to all who asked for them.

EXHIBIT OF THE COLLEGE OF AGRICULTURE, OHIO STATE UNIVERSITY

In connection with one of the exhibits, the Ohio College of Agriculture made a very attractive display of its work. This consisted quite largely of photographs of the University buildings, laboratories, apparatus, classrooms, students at work, etc. There were also large charts showing the course of study in the four-year, two-year and ten weeks courses in Agriculture and Domestic Science.

ATTENDANCE AND REGISTRATION AT FAIRS VISITED BY THE EXPERIMENT STATION FAIR EXHIBIT IN 1909

COUNTY	MONDAY		TUESDAY		WEDNESDAY		THURSDAY		FRIDAY		TOTALS	
	ATTEND- ANCE	REGIS- TRATION	ATTEND- ANCE	REGIS- TRATION	ATTEND- ANCE	REGIS- TRATION	ATTEND- ANCE	REGIS- TRATION	ATTEND- ANCE	REGIS- TRATION	ATTEND- ANCE	REGIS- TRATION
*Auglaize					10,000	169	20,000	110	8,500	9	30,000	288
Brown					1,500	51	9,000	132			19,000	285
Clark					4,148	71	5,832	100	1,208	102	20,680	193
Coshocton				3	1,300	86	16,624	322	7,813	99	25,737	507
*Defiance					458	9	4,288	59	3,985	56	8,853	124
*Erie					8,000		12,000		5,000		25,000	297
Fayette					1,540	72	11,283	52	2,488	32	1,311	156
Greene					1,235	154	10,243	154	4,431	121	16,737	446
Hardin				17	5,000	65	15,000	161	5,000	76	27,000	329
Knox				27	137	15	3,240	162	3,240	17	6,487	194
Logan					4,000		10,000		7,000		21,000	162
Montgomery					5,000		13,000	145	10,000		46,000	193
*Pike	13,000				2,000	92	10,000	67			12,000	242
*Ross					6,000	25	10,000	161	5,000	53	21,000	92
*Sandusky					2,320	38	7,248	161	9,373		18,940	252
*Tuscarawas					150	10	2,500	108	800	47	3,450	165
Van Wert					10,000	121	25,000	362	2,000	71	39,000	554
Warren					1,050		5,516	170	2,366		9,080	187
Wood					2,800		16,966		3,100		25,866	449
Total County Fairs					40,616		45,413		6,631		391,431	5,115
Franklin (State Fair)	4,782		25,041								122,513	2,640

* Attendance reported as estimated.

The Department of Agricultural Extension, which had charge of the exhibit, made a number of demonstrations with the Babcock tester; also simple experiments showing capillarity of soils, germination of seeds and many other helpful suggestions, showing the practicability of elementary instruction in agriculture in the rural schools. There was also available for examination quite a large number of books suitable for the introduction of this work into the schools and home. Particular effort was made to get in touch with the teachers of the state.

Prof. R. L. Shields was present at the fairs in Pike, Ross, Montgomery and Fayette counties and Prof. C. R. Titlow at those in Knox, Defiance, Warren and Brown counties.

WORK OF OTHER STATES

Twenty-six American Experiment Stations are using exhibits and demonstrations in connection with one or more fairs, and all report it a very effective means of bringing the work of the Station to the attention of those most in need of its aid. Minnesota reports very satisfactory results from the use of moving pictures, showing actual field work, and Maryland reports excellent results from the use of the phonograph, the cylinders used giving short talks from members of the Station staff.

HOW TO SECURE THE EXHIBIT

Persons desiring the exhibit to visit their county should get into communication with their County Agricultural Society, by which the application should be made to the Experiment Station. The application will be referred by the Station to a committee appointed by the Fair Managers' Association, which will select the fairs to which the exhibit is to be sent. Members of this committee for 1910, by which assignments have been made as given on page ii of this circular, are as follows:

Messrs. R. R. Grieve, Xenia
S. J. Vining, Celina
J. A. Knapp, Marion
A. E. Schaffer, Wapakoneta and
R. Y. White, Zanesville.

MEMORANDUM OF UNDERSTANDING

(To be used with Agricultural Societies)

Memorandum of Understanding by and between the Ohio Agricultural Experiment Station of Wooster, Ohio, and the.....County Agricultural Fair Association, duly entered in this the.....day of.....1910.

It is hereby mutually understood that, unless prevented by unavoidable transportation delays, the said Experiment Station will install one of its regular Illustrative Exhibits at the.....County Fair on Monday and Tuesday 1910 and provide not less than three men to explain the various features of the exhibit on Wednesday and Thursday and until noon Friday of that week, without expense on the part of the said Fair Association, other than will be needed to comply with the following named conditions:

FIRST: To advertise thoroughly among the people of that section the coming of the said exhibit by means of notices in the premium list, reading notices in the various county papers, circular letters and otherwise.

SECOND: To provide an expert tent man with necessary help to put up the Experiment Station tent on Monday, to take it down at 1:30 p. m. Friday and to remain on the ground during the intervening time to rectify any storm damage.

THIRD: To pay to the Experiment Station \$20.00 for the use of its water proof tent.

FOURTH: To provide such lumber as may be needed to build tables, racks, etc., in connection with the exhibit.

FIFTH: To provide two draymen, each with a flat-topped wagon, who shall be ready to move said exhibit material from the car to the fair grounds upon one hour's notice and to remove same from the fair grounds to the car promptly at two p. m. on Friday.

SIXTH: To provide two men, one of whom shall be handy with carpenter tools, to help install, tear down and pack up the exhibit, these men to report upon request on Monday and promptly at twelve o'clock on Friday and to help on both occasions until dismissed by the Station's representative.

SEVENTH: To provide a responsible night watchman for the protection of the exhibit each night.

Signed:

.....
President County Fair Board.....
Secretary County Fair Board.....
Representing Ohio Experiment Station

Approved:

.....
Chief of Cooperative Department.....
to

LIST OF COUNTIES VISITED BY THE STATION FAIR EXHIBIT

COUNTY	EARLY EXHIBITS	1905	1906	1907	1908	1909	REMARKS
Auglaize						*	
Brown						*	
Butler					*		
Clarke						*	
Clinton		*					
Cuyahoga		*					
Coshocton						*	
Defiance						*	
Darke					*		
Erie						*	
Fairfield			*				
Franklin (State Fair)	1885	*	*	*	*	*	Each year since 1885
Payette						*	
Fulton		*					
Geauga			*				
Greene						*	
Hardin						*	
Huron			*	*			
Hamilton		*					
Knox						*	
Logan						*	
Mercer				*	*		
Montgomery						*	
Meigs			*				
Preble	1904		*				
Putnam			*	*			
Pike						*	
Ross						*	
Richland			*	*			Small exhibit each year
Stark	1897-98				*		
Sandusky					*	*	
Shelby		*			*		
Summit			*	*	*		
Trumbull						*	
Tuscarawas						*	
Van Wert						*	
Warren	1891-1908					*	
Wayne						*	
Wood					*		
Wyandot					*		
40 Counties		6	9	7	8	20	In all 50 exhibits



Home from the Fair.

Ohio Agricultural Experiment Station

WOOSTER, OHIO, MAY 20, 1910

CIRCULAR No. 102

SPRAYING TO KILL WEEDS—SOME USEFUL METHODS

BY A. D. SELBY, BOTANIST

Wherever our ordinary culture methods fail us in the control of weeds, the matter of available spray solutions presents itself. This use of chemicals as sprays to destroy weeds has, heretofore, been better developed in the West, with its more limited labor supply and its restricted cropping systems. At present there seems to be little doubt that weed destroying sprays will find useful application in Ohio. Preliminary tests made last summer in cooperation with various farmers, and upon the Station farms, have given us preliminary information of considerable value.

The General Assembly has recently provided the funds for testing this matter under our Ohio conditions. This work is placed with the Department of Botany of the Ohio Experiment Station. It will be the endeavor to proceed with caution, and to cooperate with farmers, where possible, in various districts of the state which show conditions favorable to successful work.

WHAT WEED SPRAYS MUST ACCOMPLISH

What must be the line of operation or attack in the use of weed spraying chemicals? *These chemicals must destroy the weeds without injury to the crop grown.*

Most of our weeds are broad-leaved, or as we all know, plants with two seed-leaves. Our cereals and grasses are narrow-leaved plants which produce a single seed leaf. Upon the different reactions of these two classes of plants to the chemical sprays we must depend for our results—for injury to the weeds without harm to the crop. We find that *nearly all crops and weeds of the broad-leaved class of plants will be injured by these chemical sprays, and all weeds of the narrow-leaved class will escape injury by the sprays.* It follows

that crops of the clovers, alfalfa, soy beans, vetches and rape will be killed by such chemicals as destroy broad-leaved weeds, and that the sedges, quack-grass, crab-grass and wild onion or garlic will not be killed by spraying with such solutions as are not injurious to the grasses, cereal grains, etc. We may hope to destroy such weeds as mustards, dandelion, ox-eye daisy, white-top, thistles, carrot, parsnip, elders, poison ivy, ragweed, cockle-bur and horse-nettle, as well as practically all other broad-leaved weeds, by use of these sprays. At the same time, these sprays will leave blue-grass, timothy, red-top and other grasses, including the growing cereal grains, such as wheat, oats, rye, etc., without injury if properly adapted in strength and time of application.

Briefly summed up, *weed sprays, when properly adapted, should be available for the destruction of the larger portion of our pasture and grain field infesting weeds, when the methods are rightly and economically developed.* It would certainly be a travesty on our methods of culture to expect to substitute weed sprays for culture in the growing crop, such as in corn fields and the like.

WHAT SPRAYS TO USE

The most promising spray solutions tested are as follows:

Common salt solution, containing 3 pounds of salt to the gallon of water, applied at the rate of 50 to 75 gallons per acre sprayed.

Iron sulfate (copperas) solution, containing 1 3-4 to 2 pounds of iron sulfate to the gallon of water (100 pounds iron sulfate to 52 gallons of water). Use at the rate of 50 to 75 gallons per acre.

Calcium chlorid solution of same strength as salt and used at the same rate.

Sodium arsenite solution made from 1 1-2 pound sodium arsenite in 50 gallons.

Copper sulfate (blue vitriol) solution, containing 8 to 10 pounds of blue vitriol to 50 gallons of water; applied at the rate of 40 to 50 gallons per acre.

Salt has thus far proved the best spray tested in Ohio for Canada thistle, poison ivy, yarrow and horse nettle. In the Northwest sodium arsenite is given first rank. Salt is probably the most effective to destroy dandelion and some other weeds. Iron sulfate is very satisfactory to kill mustard weeds, ragweed, white-top, yarrow, and we believe a great many other broad-leaved weeds. Neither the salt nor the iron sulfate is regarded as offering any risk of application to pastures in which stock is running. Sodium arsenite is a very active poison and rather dangerous for that reason. Calcium chlorid has done very well where tested, but appears to be slightly inferior to salt. Copper sulfate solutions may be used in grain fields for mustards especially, but owing to the poisonous nature of the copper sulfate, it has a very narrow range of application.

THE COST OF SPRAY CHEMICALS

The spray chemicals mentioned are not expensive. The iron sulfate in sugar or granular form is a by-product in wire fence manufacture, and is offered at reasonable prices by the American Steel & Wire Co., of Chicago. In bags, this granular sulfate is quoted at less than 90 cents per 100 pounds, f.o.b. at principal Ohio points.

Common salt is a cheap chemical, being sold at about \$1.10 to \$1.25 per barrel of 280 to 300 pounds.

Calcium chlorid is obtainable at points in the Pomeroy salt district at a price of about \$9.00 per ton, less than car lots. It is packed in drums of 600 to 700 pounds each.

Copper sulfate is sold by almost all druggists, and costs from 5 to 6 cents per pound in barrels of 480 pounds each, or more at retail.

Sodium arsenite is rather an expensive chemical, upon which we have no quotations.

HOW TO APPLY WEED SPRAYS

The chemical solutions used as sprays to kill weeds should be applied, as all other sprays, by means of suitable spray nozzles which deposit the solution as a fine mist upon the surface of the leaves of the plant. One can use almost any good spray pump which will give good pressure, and direct the spray nozzles after the manner used in orchards and vineyards, or the traction potato sprayers can be so adjusted as to spray the whole area, instead of the row spaces only, thus applying the spray more satisfactorily.

More recently manufacturers have developed special forms of spray machinery in the West in which the force pump is run by traction, as in potato sprayers. A long rod or "boom" is attached to the rear of the sprayer, with nozzles at intervals of 8 to 12 inches; the outfit being thus driven over the grain field or pasture, secures the proper application of the spray. Certain of the western weed sprayer manufacturers have developed a "boom" with nozzles, which may be attached to any spray outfit. It is believed that these "booms," and some of the special sprayers, which, of course, are fitted with different sized tanks, will be found adapted to use in the Ohio tests. The following are some of the manufacturers of special weed spray outfits:

American Machinery Co., Minneapolis, Minn.

The Wallace Machinery Co., Champaign, Ill.

The Binks Spraying Machine Co., Fulton St., Chicago, Ill.

E. C. Brown & Co., Rochester, N. Y.

The Binks Spraying Machine Co., Fulton Street, Chicago, manufacture a special "boom" adapted to be connected with any sprayer.

WHEN TO APPLY WEED SPRAYS

In practice, the time of applying sprays needs to be adjusted to the condition of the growing crop, and the relative development of the weeds to be killed. It seems probable that very early spraying will be less effective than spraying after the weeds have developed a fair supply of leaves. The first spraying should be made not later than the beginning of bloom. Repeated applications need to be made as often as a new supply of leaves is developed, provided the condition of the host crop permits this. In grain fields, the best results will be obtained on practically all weeds, when only a single spraying is to be made, to apply the spray just as the crop is ready to occupy the land. With mustards, this will find some already in bloom. With ragweed, it is best to spray before the stems of the plants become hardened. With other weeds, of which these two are the type, as well as with these, it is often profitable to make an extra earlier spraying than that designated. For perennial sow thistle, wild lettuce and orange hawkweed, the spraying in grain fields should precede the blooming of the plants, and in cases of bad infestation with perennial sow thistle or the golden hawkweed, two sprayings should be made before the grain occupies the land. It is not clear just what can be done in the handling of bindweeds in grain fields, but similar principles will apply. For spraying in timothy or other grass meadows to kill white-top, yarrow, self-heal, ox-eye daisy and a number of meadow weeds, the principle is similar to that stated for grain fields, namely, to spray thoroughly just before the grass begins heading out. This will be during late May and early June for Ohio.

In spraying pastures to check weeds, the maximum returns will usually come from a beginning application in late June or early July before many weeds are coming bloom. After the initial application, the spraying should be repeated as often as there is development of new foliage to a marked degree.

In general, better results are obtained from applications made in cloudy weather, although any weather, except that followed by rain, is satisfactory.

SPRAYING FOR CERTAIN WEEDS

The spray applications need to be adapted, more or less, both as to kind and time of application, to the particular weeds present. This was shown in experiments to destroy poison-ivy on fences at Wooster. We had very little effect from spraying with iron sulfate, very good results from spraying with the common salt solution, and the results from calcium chlorid were slightly inferior to those from

common salt. Where the common salt was used, and two applications were made some three to five weeks apart, the poison-ivy vines were dead the following spring. Similar experiments were carried on at Carpenter, where we found that iron sulfate would have no effect upon the leaves of horse-nettle, while salt solutions were very satisfactory, destroying the crop of leaves, and forcing the plants to put out new leaves. Under these conditions we expect, by two or three successful sprayings, to kill a large share of the weeds in a single season—the more resistant plants being given a repetition of the treatment the next season.

In the case of mustard weeds, very good results have been obtained by the iron sulfate solution, and there is little difference in the results obtained upon timothy meadow weeds in general, such as white-top, yarrow, self-heal and several others, as between the applications of iron sulfate and those of common salt. On the other hand, Canada thistle is not destroyed satisfactorily by iron sulfate solution. It is killed down quite well by the common salt, and our western friends report even better results by the use of sodium arsenite.

Upon ox-eye daisy we need to have further tests, as well as upon a large number of different plants.

For dandelions the matter is an open question whether iron sulfate solution, or the common salt solution is the better for the purpose. We have made partial tests through two seasons at Wooster, and find that the first spraying should be made before any of the plants come into bloom, and that two or three later sprayings will probably be found profitable during the season.

WE HAVE YET TO LEARN ABOUT SPRAYS FOR SEVERAL WEEDS

As previously stated, in 1909 we learned what to use and how to spray, to keep down poison-ivy and horse-nettle, as well as white-top and yarrow. We have yet to learn the best way of handling ox-eye daisy, wild parsnip, iron-weed, osier willows, milkweed, velvet-leaf, bladder ketmia, bindweed and a large number of other common weeds.

The object of the work upon which we are now engaged is to determine just how to apply the sprays, and what sprays to use for the eradication of these weeds under our Ohio conditions. Of course, we realize that what has been done in other climates, upon the same weeds and plants, has more or less suggestion in it for Ohio. Nevertheless, our different climatic conditions may give very different results from those obtained in the Northwest.

IS WEED SPRAYING A PROFITABLE BUSINESS FOR OHIO?

As before intimated, it is yet to be proved whether weed spraying is a profitable business proposition under our Ohio conditions. We are entering upon this work in the spirit of inquiry. The small amount of work done in 1909 indicates some very desirable results within our reach with respect to freeing our Station farm and Test farms from such persistent growths as poison-ivy and horse-nettle. The Station hopes to investigate this matter of weed spraying in the spirit stated, and to be able to give, the results obtained, in the course of time, for the benefit of the public.

Whoever has no troublesome weeds will have no use for weed spraying. Whoever has troublesome weeds through slovenly methods of culture in cultivated crops, such as corn and potatoes, is not likely to be greatly assisted by weed spraying; but grass meadow lands, pastures, roadsides along our highways, along railroads and electric lines, and such grounds as parks and lawns, are open and offer a very wide field for determining the usefulness and profit of chemical sprays to destroy the weeds in them.

Ohio Agricultural Experiment Station.

CIRCULAR No. 103

Horticultural Series No. 3

WOOSTER, OHIO, JUNE 12, 1910

AUTUMN MEETING OF THE OHIO STATE HORTICULTURAL SOCIETY

LITTLE HOCKING, SEPTEMBER 17, 1909.

STATE FAIR MEETING, 1909

On account of the regular midseason meeting which was being advertised for September 17th, the State Fair Meeting was but an informal session, no program having been arranged. The members of the Executive Board were required to meet at this time, however, as the secretary's tenure of office had expired on the first day of August, 1909. The result of the Board Meeting was that F. H. Ballou was re-elected secretary for the ensuing year.

A standing committee was appointed, consisting of Messrs. W. J. Green and F. H. Ballou, for the purpose of endeavoring, if possible, to solve a number of problems relating to nomenclature of varieties of apples which have been causing confusion among exhibitors at the State Fair for a number of years.

AUTUMN MEETING AT LITTLE HOCKING, SEPTEMBER 17, 1909

This was one of the most excellent and successful midseason sessions in the history of the society. The meeting was held in conjunction with the Little Hocking Grange in the orchard of Mr. Chas. W. Oakes, three and one-half miles below Little Hocking, on the Ohio River. While this point was considered somewhat inaccessible because of its distance from the railroad station, and some doubt as to attendance seemed to exist, it proved that all uneasiness on this point had been quite unwarranted. The day chosen was perfect, and the boat which had been chartered at Parkersburg, W. Va., especially for the occasion, carried down the beautiful Ohio River, soon after sunrise, a generous company of enthusiastic, appreciative horticulturists who were out for what might be learned at the meeting.

Aside from the boat load of excursionists, the residents of southern and western Washington County turned out in goodly number, many driving several miles to attend the meeting. A number of horticulturists from distant parts of the state was in attendance. It was estimated that there were present 500 persons—all interested in the wonderful results in fungus and insect control that had been wrought by the horticultural department of the Experiment Station in Mr. Oakes' orchard.

The large, 34 year old Rome Beauty apple trees of this orchard, where thorough spraying had been done, were heavily laden with large, smooth, sound, perfect apples while the unsprayed trees in the same orchard, and all orchards which had not been sprayed throughout the neighborhood and all that part of Ohio were producing only meagre crops of miserably small, scabby, wormy worthless fruit. It was a demonstration long to be remembered and one that will prove productive of a great awakening as to the possibilities of apple culture in south-eastern Ohio. The following papers were presented:

SPRAYING FOR THE FUNGOUS DISEASES OF THE APPLE AND OTHER CROPS

By A. D. SELBY, Ohio Experiment Station

"What is a fungus disease?" will be often asked in connection with such a title or with titles referring to diseases of plants caused by parasitic fungi. Around one's views or understanding, or, I might say, one's apprehension or grasp upon ideas of parasitism and the resultant effects of it upon the host crop or plants, we must group the opposed or opposing forces of our remedies, such as spraying, seed treatments, selection of resistant and relatively immune sorts and other possible agencies for the prevention or amelioration of crop losses through fungus diseases.

Should you ask me about my notion as to fungus diseases, I might reply that succinctly they are diseases produced in plants as a result of the attacks of parasitic fungi or bacteria. Further, these diseases are characterized by the way the parasite is propagated and scattered, which is usually through spores of microscopic size, and by any conveying agency, such as winds, movements of insects, animals or even of man. Further, that these diseases are not only favored or held back by reason of the special characters of the host plant, such as relative liability or immunity in being attacked, but also that other things being equal, these diseases are enormously swayed or controlled by the conditions existing, at any point, with respect to the moisture, especially that held as air humidity and by the temperature of the air which surrounds both the crop or host plant and the attacking parasitic form.

Our host plants, our crops have their optimum of moisture, temperature, etc. Their parasites have a very similar and often analogous and inter-related optimum of these very same conditions.

Viewing these processes of parasitic attack from the objective of their possible control, what is the basal principle, or what are the means to this end?

Inevitably there will be two viewpoints, viz.: 1. That of the plant or crop diseased, and 2. That of the parasitic fungus or bacterium. We are most concerned today with the side of checking the parasitic fungi which attack the apple, the potato and tomato and possibly the muskmelon. Upon the crop we must not inflict more injury than the parasite would have done. As to checking the parasite we must have a principle which is the basis for action. What is this principle? My friends, each of you formulate it in your own minds as I ask each one.

No simple formulation is without objections. I like this one: Disinfection of the crop. The principle of parasitic disease prevention through spraying rests upon the same basis as the treatment given to rooms in which patients have been ill from diphtheria, scarlet fever and smallpox. Both seek to kill, to destroy the spores or other propagating parts of the parasites—that is, to destroy the microbes, the conveying germs of the disease. I emphasize this matter of the

principle of disinfection by the use of fungus killing substances, called fungicides, because our mutual understanding of this matter rests upon the principle and the further fact that these spray or seed treatment substances will destroy the spores and other living parts of these fungi. It is not the moonshine, the weather or the presence of something away outside we are fighting. It is a number of actual living parasites which cause our losses. Although we may never forget that the moisture and temperature of weather conditions are of very great influence, these influence these diseases only as they favor the development of the parasite out of proportion to their influence on the host crop. When this happens the return from the host plants is disappointing to the grower.

THE USEFUL FUNGICIDAL SPRAYS

When we have infection through the spores or other parts of these parasites we are called upon to treat for the parasites. The disinfectants or sprays used on our crops are of different composition. For use on crops or trees in foliage the most used fungicides contain copper compounds as the active agent—Bordeaux Mixture, Bordeaux and Iron Sticker, Ammoniacal Copper Carbonate and Soda Bordeaux Mixture—all rely for their efficiency in killing fungi upon the copper compounds they contain in their final chemical forms.

In addition to the copper salts there are certain sulfids or soluble compounds of sulfur and some base, such as Potassium, Calcium (Lime), etc., among our fungicides. These appear to rely not on the base nor upon the sulfur but upon the particular combination produced in the making.

Potassium sulfid solution and more latterly self-boiled lime-sulfur mixture are examples of useful sulfid sprays. Self-boiled lime-sulfur mixture of the 10-10-50 formula may be used upon the foliage of the peach without leaf injury.

The following are the formulae of these sprays as published in the spray calendar, Bulletin 199, December, 1908.

No. 1 Bordeaux mixture.

Copper sulfate (blue vitriol)..... 4 lbs.
Quicklime (not air slaked).....4 lbs.
Water to make 50 gallons.

No. 3 Ammoniacal copper carbonate.

Copper carbonate.....6 ounces
Ammonia.....about 3 pints
Water, 50 gallons.

No. 7 Bordeaux mixture and iron sticker.

Copper sulfate (blue vitriol).....2 lbs.
Iron sulfate (copperas) 4 lbs.
Quicklime.....6 lbs.
Water to make 50 gallons.

No. 10 Self-boiled lime-sulfur mixture. (As now recommended by the originator, W. W. Scott, U. S. D. A.)

Stonclime.....10 lbs.
Flowers of sulfur.....10 lbs.
Water to make 50 gallons.

The effective copper compounds of the Bordeaux mixture type have a philosophy that will bear repeating. You understand how vital to the health of the leaf of any fruit tree to the crop producing power of the tree and that remedies, if applied after the leaves are injured are too late to be of high usefulness. You

understand also that an apple after it has once been attacked by apple scab can scarcely be saved to the high class merchantable apples. The more useful sprays must be of such constitution and capable of such application that the spray is continuously present during the period of infection.

The continuous attacks of apple scab in the early season must be met by the continuous presence of an active fungicide. Were we to get all the growth of new shoots and foliage on the apple as promptly as upon some other fruits, the number of sprayings to be made would be modified. As it is in fact, the sprays require to be made to meet the conditions of new leaf cluster shoots as well as those of the blossom shoots upon the new growth of the season.

The effective copper compounds in the Bordeaux mixture are those copper salts precipitated in insoluble form by the addition of lime to the solution of copper sulfate. Formerly it was held that the compound thus precipitated is copper hydroxid. Now Prof. Pickering, of England, holds that various basic sulfates of copper are produced. In either case the compounds produced and applied to the trees are relatively insoluble when applied.

Once upon the trees these become soluble by the action of the carbon dioxide and the moisture in the air and are therefore present and immediately available when such are needed to check parasitic fungi.

With Bordeaux mixture and iron sticker the same conditions hold with the added sticker qualities believed to be present and to act in such a way as to make the action more prolonged and just as effective, or very nearly so.

Formaldehyde formulae for treating potato scab, oat smut, stinking smut of wheat, onion smut, etc., as well as a formula for corrosive sublimate applied for potato scab are published likewise in the Spray Calendar, Bulletin 199.

APPLE BLOOM AND APPLE SETTING IN 1909

Apple blossoms were much more numerous in 1909 than the present set of fruit would lead one to infer. In southern and central Ohio especially, the failure of the trees to set fruit or even to fecundate the blossoms was apparent quite early. Specimens were received from Gallia county quite soon after blossoming. These showed that only about 5 to 7 percent of the blossoms had formed fruits. A similar state of facts held in Jackson county, in Fairfield county, and doubtless in many other districts. In the first counties named, the orchards had not borne a crop in 1908 and the trees bloomed quite freely. The fruits were not there for the apple scab to take off if it were there to do so. But these trees and many others were too much pushed to get through last season's severe drought. It would seem that the stress from the drought resulted, with non-bearing trees, in reducing the food reserves so much that not enough vigor remained to insure fecundation of the blossoms formed despite conditions. On the other hand, bearing orchards of 1908 were often so much reduced in vigor by the drought that no blossoms or next to none were formed and no fruit was set.

I know that many persons who had a fair bloom on their trees last spring were much disappointed in the crop set by the trees. The explanation seems to lie in the exhausted tree reserves from drought of 1908. This again emphasizes the very important function served by the stored food reserves in the tissues of the fruit trees and should stimulate us to orchard methods which will insure the needed reserves even in stressful times.

SPRAY FOR APPLE FUNGI IN 1909

Plans were made for rather thorough spraying work on apples this season through the cooperation of the departments of Horticulture, Entomology and Botany. I shall speak only in relation to the Botanical side of the work so far as indications yield results now. The final results will be learned when the crops are gathered.

The weather was somewhat earlier and cooler during the apple blooming this season than in 1908, and the blossoms came earlier. However we had in most parts of the state an excess amount of showery, muggy weather before the trees were out of bloom. Indeed conditions for scab development were very favorable. The scab did not fail to get to work on the fruit where there was a chance and to attack foliage in all instances.

We planned in most spraying tests to compare Bordeaux mixture with Bordeaux mixture and Iron Sticker. At Carpenter, in addition, Self-Boiled Lime-Sulfur made a three-sided comparison.

Besides the scab the presence of an apple louse, *Aphis sorbi*, on many apple shoots complicated affairs. The secretions of these lice invited the sooty fungus and it made a very early appearance, showing about June 1 to 10 both before and after bloom.

Even the two spray treatments did not prevent all scab development upon the interior fruit clusters. However, the sprays usually saved enough fruits to tax the power of the trees to develop them on these interior clusters. Where these conditions of scabby fruit and sooty fungus were most noticeable at Chillicothe, the spraying just before the blossoms opened was rather imperfectly done and the proportion of scabby fruits was much larger than at other points where first spraying was done thoroughly. However, as the fruit crop was so disappointing in many orchards of Southern Ohio our observations were much more limited than had been planned.

In Northern Ohio, where weather conditions of last year as well as the present season have been more favorable in many ways, fine crops of apples have been saved at North Amherst and Erlin, Sandusky County and with very little scabby fruit. Detailed results are not yet available but the total outcome is satisfactory.

There is nothing to modify my judgement of one year ago, namely that spray applications of fungicides need to be made both just before the blossoms open and just after the bloom drops to insure successful results in scab prevention.

At Erlin, Sandusky County, Mr. Stokes has very fine results of scab free apples and has kept his crop this year on Winesap variety. He has used Bordeaux and Iron Sticker throughout the season, the Calendar formula 2-4-6-50 may have been partly used on early sprays but latterly and chiefly 2 lbs. copper sulfate, 2 lbs. iron sulfate and 4 lbs. lime were used. He had practically no spray injury.

The sooty fungus has apparently extended itself much less than was feared earlier. Have many of you observed recent development of a black sooty growth on the surface of the apples?

SPRAY INJURY IN 1909.

Spray injury upon apple foliage has been very severe on some orchards in southern Ohio this season and in northern Ohio there has been little or no complaint. The difference in injury may be explained in part by the differences as to rainfall and humidity in the two sections at critical periods. At Chillicothe

and Carpenter, we had abnormal leaf injury from the sprays which in the former case may have been due to abnormal soil conditions, since the orchard became in part defoliated in 1908. Another curious fact was the much larger interval than we usually expect to transpire between the spraying and the leaf yellowing and dropping. In these experiments we used the standard formulae of Bordeaux mixture, Bordeaux mixture and iron sticker, and the self-boiled lime-sulfur mixture.

At Chillicothe, on the same varieties, notably Mann and Grimes Golden, the leaf dropping was two and a half to three times as bad as on the trees sprayed with Bordeaux as it was on adjacent rows sprayed with Bordeaux and Iron. At Carpenter, we had self-boiled lime-sulfur as a further comparison. On the trees where lime sulfur was used, scab was not quite kept down and there was little leaf fall. Where Bordeaux and iron was used there was also light or moderate leaf fall, but on the trees treated with straight Bordeaux the trees were almost entirely defoliated.

I am impressed with the possibilities of the Bordeaux and iron mixture, using slightly reduced amounts of iron sulfate, say 2 to 3 pounds to 50 gallons as an apple spray in the future, but I can not in critical cases expect much less spray injury than from Calendar Bordeaux and iron formula since it is the copper compounds that seem to be responsible for the injury to foliage.

SPRAYING FOR TRUCK CROP DISEASES

Muskmelons—In the matter of muskmelon diseases we must remember that there are two distinct types of melon diseases which are liable to be called "blights". One of these types is a true leaf or foliage disease known as leaf blight and in some seasons is supplemented by the work of downy mildew. These leaf diseases are amenable to spraying. Perhaps even more conspicuous than these are the wilt diseases of muskmelons and cucumbers, which also attack watermelons. In the wilt disease the organism attacks usually at the root of the plant and causes sudden wilting; sometimes, however, through the action of biting or sucking insects, the organism is inoculated into a branch or into the vine some distance from the root. In this case the part beyond the affection dies after sudden wilting. We really have two distinct wilt diseases. One of these is due to a wilt infesting *fusarium* and the other is due to bacterium. Both of the organisms are more likely to be found in soil where melons or cucumbers were grown the year previous. Both of them are also liable to be spread by the attacks of biting or sucking insects, such as stink bugs, leaf beetles, etc. With the wilt disease you can only gather and burn the wilted plants in order to keep down the infection. There is no spraying remedy.

In spraying for a foliage disease, and especially for the leaf spot or leaf blight of muskmelon, one needs to get at the work, as in other spraying, before the damage is done. It seems wise to spray after the vines are one or two feet long, and to keep at it throughout the remainder of the season, seeing that the vines are covered with the spray. This should be accomplished by spraying at intervals of two to two and a half weeks. The best spray seems to be Bordeaux mixture, reducing the strength to three pounds. Muskmelons are very susceptible to Bordeaux injury, or spraying injury, in seasons like the present one, and this manifests itself by yellowing of the leaves in a narrow belt around the leaf border. Perhaps some of you can call to mind conditions of this kind in your sprayed crop of melons this year. You will doubtless recall a yellowing of

leaves in sprayed melon patches, but this affects segments of the leaves around the border rim. Because of the danger of spray injury it is best to keep the strength of bordeaux for muskmelons down to the 3-3-50 formula. The 4-4-50 formula may be used without risk on cucumbers, however.

Tomatoes—On tomatoes, seasons like the present soon bring out a great deal of leaf spot. This leaf spot is a true fungous disease, and the dropping of the leaves shortens the crop very seriously. This was true in my own garden at Wooster the present season, but since I was attending to other people's truck patches my own had to be neglected. In your district where the growth of early tomatoes and the use of the stake method of planting is practiced, you are liable to inroads of the leaf spot fungus. However, this leaf spot fungus will tend to hasten the ripening of the fruit, and increase the yield of them, at high prices. The bordeaux mixture is a very successful spray against the leaf spot, and could be applied from the time the plants are one to two feet high until the crop is made. However, the spraying and keeping down of the leaf trouble will delay the maturity of the crop, and while the crop will be greatly increased the actual profits may not be much greater from the sprayed tomatoes than from the unsprayed ones. This seemed to be the condition more especially a few years ago when I was conducting some experiments in tomato spraying in cooperation with Mr. Chas. F. Dyer of Marietta. Possibly other conditions may have come in and I invite your impression about them.

Tomatoes are also attacked by wilt diseases of two kinds; one due to a fungous *fusarium*, and the other due to bacterium; but in both these wilts the only thing is to remove and burn the diseased plants, as with muskmelons. In the case of fruit spots, to which you are not very subject in this region, so far as I know, the bordeaux spraying will yield fine results in keeping down the decays of the ripe fruits, or of the fruits from near the time of ripening. The spraying on the other hand will not be effective in keeping down the point rot of green tomatoes, which is very liable to occur in dry seasons like last year, or if the spray will prove to be ultimately successful as yet it is only partially so. We seem to have in dry seasons a bacterial infection of the blossom end, and as yet our spraying methods have not been adapted to prevent this serious infection. At this time we can only express the need of more knowledge.

Potatoes—In spraying potatoes in this part of Ohio we may leave out of ordinary consideration the prevention of late blight. It is true that occasionally on wet, cold seasons, and with very late planted potatoes, we may have some late blight this far south, but this will probably not happen oftener than once in 10 or 15 years. With the early blight, on the other hand, and the predisposition in southern Ohio to periods of early summer and midsummer drought, we are very liable to have serious outbreak. Whenever these early summer conditions result in abundance of leaf sucking and leaf puncturing insects, especially flea beetles, we may count on diseases following rapidly in the wake of the insect injuries. With normal seasons, the results of potato spraying are to be expected to show a small profit value, not a large one. In abnormal seasons like 1908 thorough spraying of a crop in this region should yield a good profitable balance. You will understand the spraying is made to keep down the infections from the early blight fungus, and to prevent the collapse of the leaves in the manner described as tip burn. From the results of the last two seasons the bordeaux mixture 4-4-50 formula, and bordeaux and iron sticker of about 2-3-5-50 formula, may be safely recommended for potato spraying.

Recently in northern Ohio, starting at the Experiment Station, we have had a serious development of the potato dry rot, *Fusarium oxysporium*. Not only did this fungus kill out a small area of plants entirely in potato plots, but it is now believed to be the cause of premature dying of the larger part of the potato plots. The infection from this fungus may come either through the soil or through seed. I believe that in the present case it may have come, partly at least, through the seed, and we are just now endeavoring to make a careful field study of the trouble. The indications are that locally it is often confined to fields on particular farms throughout the northern Ohio potato region that have this premature dying of the potato tops, even where thoroughly sprayed. This will be explained by the seed infection and would not prove that spraying is without value. We wish to learn the actual state of affairs before offering much more than caution in the choice of seed at this time.

Q. We have a moderate crop of Ben Davis, with a little scab; a few Rome Beauty; the Grimes Golden are quite perfect, and no scab; they are quite free from fungus diseases. Now do they need spraying or not?"

A. "Ben Davis, Gano and Baldwin will come nearer producing a perfect crop without spraying than any others. Rome Beauty, White Pippin and Winesap are the other extreme. We did not prevent all of the apple scab by spraying in Chillicothe. I think that probably there is a different rate of development of the scab in the Grimes. I do not think that you can grow Grimes ordinarily without spraying."

Q. "How about spray injury?"

A. "Leaf injury is the more vital. Spray injury this year was a little strangely marked. Spray injury developed this year where no spraying was done. We had previously thought that it was caused exclusively by spraying, but it came to a certain extent this year where no spraying was done. There was a rusting on unsprayed trees. The injury from spraying is much less than from the apple scab. The injury from spraying might place the apples in second class, but many people say that they still sell as first-class apples."

Q. "Have you sprayed peach trees successfully?"

A. "Yes."

Q. "How much spray do you put on?"

A. "There are two features in peach spraying. All Chinese types like Elberta and Boyer are very liable to leaf curl. Spray before the blossoms open with lime-sulphur or Bordeaux mixture, for the leaf curl on the Elberta. With the Salway, Late Ware, Morris' White, and Heath Cling, spray the foliage with Bordeaux mixture, two or two and a half pounds to five, as eight pounds will

injure the foliage too much. Self-boiled Lime-Sulphur is successful as it will not injure the foliage. Use a 10-10-50 formula. This will not injure the foliage of peach trees and will give fine results. Make two or three applications."

Q. "How about summer spraying for apples?"

A. "You can prevent apple scab by using Lime-Sulfur in the summer time. This was found out in New York. Bordeaux mixture is much worse than Lime-Sulfur. If we can be as successful as the New York people were this year with Lime-Sulfur it is well worth trying. Bordeaux mixture is being used in some parts of the country with success. However, some people say it cannot be done."

Q. "Can you spray plums?"

A. "You can spray plums of the European varieties with standard Bordeaux mixture. If you spray the Japanese and American varieties at all use self-boiled Lime-Sulfur."

After dinner Mr. Selby showed apples from Carpenter. Those which had not been sprayed had much sooty fungus and scab. Those sprayed with Bordeaux mixture had a little spray injury, and there is danger of injuring next years crop through loss of foliage this year. He also showed apples sprayed with Bordeaux and Iron Sulfate, which were in excellent shape, and free from blemish. Those sprayed with Lime-Sulfur had a little scab and sooty fungus.

SPRAYING FOR INSECT FOES OF THE ORCHARDIST

By H. A. GOSSARD, Ohio Experiment Station

Ladies and Gentlemen:—The orchard in which we are assembled represents a part of a general orchard plan entered into by the departments of horticulture, botany and entomology of the Experiment Station for the purpose of demonstrating that Ohio can grow apples in competition with any other parts of the United States. More or less experimental work in orchard spraying has been done by the Experiment Station throughout the period of its history, but one of the notable experiments in spraying was conducted by the Department of Entomology in the orchard of the Messrs. Schmitkons of Lorain in 1907. This orchard comprises about 25 acres of trees, something like 20 feet tall, with an equal spread of limbs. The principal varieties represented in the orchard are Baldwin and Ben Davis, but 25 or 30 different varieties are grown. During the season of 1907 the gross return for the crop was somewhere in the neighborhood of \$4500 while the cost of treatment was less than \$200. The spraying was done with a gasoline power sprayer having a 250 gallon tank and a tower built over the trucks so that one of the operators standing on the tower would have his feet elevated 5 or 6 feet above the ground and with a bamboo pole 10 feet long was enabled to reach into the tops of these trees very conveniently. At the end of the rods were used some goose-neck crooks made by bending gas pipe at

an angle of 15 to 20 degrees. Most of the spraying companies now make these crooks, or at least angled nozzles. However, they can be made by the local blacksmith from 3 or 4 inches of gas pipe threaded at each end; one end to screw into the end of the extension rod and the other to fit into the nozzle. When the rod is extended at something of an angle, the additional angle given by the crook throws the spray downward and into the cups of the bloom. When apples first bloom the flower end is turned skyward and the apple remains in this position for about ten days or two weeks after the petals fall. Since about 90 percent of all the codling worms enter the apples through the calyx cup it is very essential that a goodly amount of poison be driven into the flower ends of the apples so as to destroy the worms when they take their first meal. It is also desirable that considerable power be employed to drive this spray to the desired location. From 100 to 150 pounds pressure is advisable, but good results can be obtained with lower pressure provided the operator is persistent enough to remain at the same tree until it is fully covered. Upon all these trees we used from 10 to 15 gallons of spray for the first spraying after bloom. The greater part of the orchard was sprayed with Bordeaux mixture in combination with arsenate of lead. The first spraying had 4 pounds of copper sulfate, 6 pounds of lime and 3 pounds of arsenate of lead. For the second spraying about two weeks after bloom the copper sulfate was reduced to two pounds and a considerable part of the orchard was not sprayed in this second treatment. A third spraying with arsenate of lead alone, using three pounds to 50 gallons of water, was given in the latter part of July to some of the plots. There was considerable injury from Bordeaux burning both on fruit and foliage. However, the apples ripened up quite satisfactorily through the russeted skins, and the fruit was first class at harvest time though, of course, it would not go as fancy fruit. However, there was no difficulty in disposing of it at \$3.50 per barrel, and a great many barrels were disposed of locally at \$1.50 per barrel. During 1908 we transferred our operations to an orchard of about 14 acres located a few miles from Fremont in Sandusky county. This orchard is the property of Mr. J. A. Stokes and the trees in one of the 4 acre blocks were about 22 years old, in another 4 acre block about 20 years old and in another from 12 to 15 years old. There were two acres of very old trees—40 to 50 years. We likewise used a power sprayer here. Owing to the great size of the trees we were not able to reach the tops of them so satisfactorily as in the Schmitkons' orchard. However, by putting on a brass extension of three or four feet to the end of the 10 foot pole, we succeeded in covering the tops of most of the trees. We used weaker mixtures in this orchard than the preceding year, the principal formula being 2 pounds of copper sulfate, 3 pounds of lime, and 3 pounds of arsenate of lead to each 50 gallons of spray. On some of the plots arsenate of lead alone was used at the bloom, and then a fungicidal application was given 10 days or 2 weeks later. The fungicides used for this purpose were Bordeaux mixture, self-boiled lime-sulfur made with cold water, and commercial lime-sulfur. The fungicidal applications were a little too late, we think, to give best results and some scab developed on all the trees that were left until the second spraying for the application of fungicide. Very little scab developed upon the Ben Davis and Baldwin trees that were treated with Bordeaux immediately after bloom, but was quite conspicuous upon the Winesaps and a few other varieties especially susceptible to scab.

The orchard had been sprayed very thoroughly with lime-sulfur wash just as the buds were swelling and this doubtless contributed very much to hold the scab in check. There was practically no burning of fruit in this orchard, but

the weather was almost ideal for spraying at the time the application was made. From this 14 acres of orchard the gross receipts for the crop of 1908 was \$7,400. A single acre of Ben Davis trees yielded about \$1,408 gross, or more than \$1,000 net. The trees for this acre were not selected in any way, but every tree in the block was counted whether it had on it few apples or many. During the present season the Department of Entomology has had a number of different orchards located in different quarters of the state, under treatment. One of them is the Schmitkons' orchard, already mentioned; another is the Stokes' orchard, which gave a heavy crop in 1908; another is located at Mantua in Portage county; one is in Gallia county; another in Jackson county: then we are using the Station orchard at Wooster; also a small family orchard of three or four acres near Wooster. The orchard at Mantua has been defoliated by canker worms a number of seasons, and we therefore anticipate a light crop upon it this year, but see no reason why it should not give a good return next season. The orchards in Gallia and Jackson counties suffered so severely from drouth last year that they did not have sufficient vitality to hold their crops this year, though they bloomed heavily. We are confident that they will produce a good crop next season unless frosts or something of that character intervene. It is our desire to carry on experiments in all these orchards through a period of years so that we may strike an average and know what we can reasonably expect from Ohio orchards.

The greatest consideration in spraying apples is to be sure that enough liquid is applied. Do not be afraid of wasting a little spray. It is not wasted, even if it does run off on the ground. The old idea of employing a mist spray and ceasing the application before dripping begins, is not so successful as a heavy application. I believe there is less burning of foliage when the trees are sprayed until they drip, because in that case the leaves are bathed with the spray, all of the spores of disease are thus destroyed, and instead of the drops collecting on the bottom sides of the leaves, remaining there and burning the edge of the leaf, they roll onto the ground, leaving a comparatively small amount of spray adhering to the lower edge of the leaf. I prefer making the spray very weak and using an abundance of it. Trees such as you see around you, will need from 10 to 15 gallons of spray, depending upon their size, for the first spraying after bloom. If this spraying is thoroughly made the crop for the year is practically insured whether or not any additional applications are given, though it is advisable in many cases to give a second and oftentimes a midsummer application. If growing fancy apples, it may be necessary to spray even oftener, but good salable apples, free from worms, can be obtained in the manner I have described. For southern Ohio and for varieties of apples that are particularly susceptible to scab, I presume it is the part of wisdom to spray with Bordeaux mixture after the leaves appear and before the trees are in bloom. If a very thorough spraying is done with lime-sulfur just when the buds are opening I am inclined to believe that some varieties in the great majority of seasons will need no spraying with Bordeaux until after the bloom falls.

Regarding the question of pumps, orchards of six acres and upward should have a power sprayer of some description. Personally, I prefer a gasoline engine as a source of power, but traction sprayers and compressed air sprayers are adapted to certain uses and of course deserve consideration. For orchards of 4 to 6 acres, powerful hand pumps or power hand pumps, capable of maintaining a pressure of 80 to 100 pounds without overworking the man at the pump

handle, are desirable. For smaller orchards barrel pumps are used, but where there are only from one to a half dozen trees, bucket pumps may be used, though they are somewhat inconvenient for such use.

It will cost from 25 to 50 cents per season to spray one tree of the average size shown in this orchard. Such trees ought to give from 8 to 15 bushels of apples each, and since they produce very little if unsprayed, it is readily seen that the profit from spraying each tree will range from 5 to 12 dollars if apples bring in the neighborhood of one dollar per bushel. Since our population has increased so much in late years, while the orchard area all over the country has decreased owing to the ravages of the San Jose scale etc., it will pay every owner of apple trees, whether he has one tree or many acres of orchard, to take good care of them. In fact, there is no part of the farm that will pay a higher dividend on care and attention than the apple orchard.

Q. "Do you use arsenate of lead with Bordeaux mixture?"

A. "Yes. We use it with Bordeaux mixture. It is all right."

Q. "Why does Mr. Gossard prefer arsenate of lead, at 10 cents per pound, instead of Paris green, at 30 cents per pound?"

A. "Arsenate of lead kills more worms than Paris green, and sticks on the trees much longer. The extra cost of arsenate of lead is much more than paid for by the larger crop."

Q. "How much spray mixture do you apply at a spraying?"

A. "Ten or twelve gallons at an application after blooming."

Q. "But will it not run off the leaves? I only use about three or four gallons. Is more necessary?"

A. "It will drip, but let it keep on dripping. My observations lead me to believe that when only enough spray is put on to stick that it sticks on the leaves in drops and is likely to burn holes in the leaves. When it runs off the leaves are freer of fungus and there is less liability of leaf injury."

Q. "What is the cost of spraying trees the size of these (30 years old), three times each?"

A. "I think that it costs about 40 cents or 50 cents per tree for a season's spraying. Possibly a little more."

Q. "What is the trouble when peach trees live one or two years and then die? What is the matter?"

A. "It might be borers, but I could not say without seeing the trees. It might be yellows or some other cause."

Q. "How do you get rid of the borers?"

A. "The borers are caused by a moth that lays its eggs in the bark of the tree near the base of the trunk. If you have only a few trees dig out the worms with a knife and kill them. It may help to spray with Lime-Sulfur. Bank the trees to a height of eighteen inches with earth and leave it until the first of October and then

remove it and give the trees a chance to harden up before winter. This will make the moths go higher up on the trunk to deposit the eggs. By running a wire into the holes where the borers are you will likely kill some of them."

Q. "What do you do for bitter rot?"

A. "That belongs to Mr. Selby."

Professor Selby: The bitter rot spray has to be applied after the other applications. If you are treating for the bitter rot follow up the spraying for the codling moth, rot and scab with two or three applications of ammoniacal copper carbonate as described in the spray calendar. This will not injure the salability of the fruit, as Bordeaux mixture will. Mr. Cox says that Bordeaux mixture will not injure the salability of the fruit, but our conditions are farther north than Mr. Cox's.

Q. It has been difficult for me to save my Smith Cider for the past three years. We had the brown rot, which comes in as ripening time approaches. It is light brown to black in color; what is the remedy?

A. There are two rots, the brown and the bitter rot. They have very much the same appearance, being small, circular depressions, but the brown rot is a lighter color than the bitter rot. The bitter rot is usually a very dark color, nearly black, while the brown rot is a comparatively light brown. If you taste an apple that has an advanced stage of the bitter rot, you get a decided bitter taste. If you taste an apple with the brown rot the bitter taste is not noticeable. The treatment is given fully in the spray calendar, bulletin 199, of the Experiment Station.

Q. Has the Station tried a preparation called "Scalecide"?

A. Yes. We have used it. It is a good remedy for the San Jose scale.

Q. Can you use it in the fall?

A. It may be. It is used in the fall pretty generally over the United States without any bad results. I think it is all right.

Q. What can you do for pear blight?

A. There is no satisfactory remedy for pear blight. Perhaps Mr. Selby can tell us more about it.

Mr. Selby: I do not think that any man can grow certain varieties. I do not think that any living man can succeed with Flemish Beauty or the Bartlett in this region. Most people in this region can succeed with the Summer Sugar Pear or the Seckel, which seem almost immune from blight. Least, probably the Keiffer. Next and in the same class will come the Duchess, Sheldon and possibly the Anjou.

The blight is produced by a bacteria which lives over on the blighted wood. At the time when the pears bloom this bacteria secretes a substance from the spores. The bees visit this secretion, and then go to the blossoms, and the fungus develops in the nectar and pollen of the blossom.

Use Lime-Sulfur spray and cover the trunk of the tree. There is no specific remedy for pear blight. Cut off the blighted wood and burn it. It may be cut off now, but be sure and do it again before the trees bloom in April.

Q. Can grape rot be controlled?

A. We have handled all of the commercial varieties and grown them successfully. The treatment is all boiled down in the spray calendar, and the results are all shown in the bulletin of the Station "Spraying For Grape Rot". Get to all the new clusters before the blossoms open; otherwise the black rot fungus will get ahead of you; then spray after the blossoms fall.

With regard to the Norton Seedling will say that as it is a special case it requires special investigation to solve it.

Q. Why is it that some varieties do much better on the side of a building than they do on a trellis?

A. The explanation probably lies in the fact that when they are on a building there is less opportunity for moisture to collect on the clusters of grapes, thus affording less opportunity for the fungus to work on them.

APPLE GROWING IN SOUTHERN OHIO

By U. T. COX, Proctorville

At the New York State Fair I saw results of spraying with the lime-sulfur solution, a commercial brand, for apple scab and there was no russetting of the fruit at all and where sprayed with the Bordeaux it was very rusty and some of it deformed. It seemed to be a better spray than Bordeaux as they used it, giving as good results in preventing scab with no injurious effects. They added arsenate of lead for the codling moth with good results, notwithstanding Mr. Gossard saying it will not do. As he has strongly urged thorough work in spraying I want to emphasize the fact and add that if three men are to run a hand spraying outfit I advise putting two of them on the pump handle and one to hold the nozzle. Two men can give good pressure and one can not, and under high pressure the liquid will be discharged as fast from one nozzle as from two with ordinary pressure and it will spread better and do much more effective work than with low pressure. A power sprayer is the only thing for effective spraying if one has enough orchard to justify such an outfit. It does not require a very large orchard for one machine to pay for itself either. In the west they have an outfit for every 10, 15 or 20 acres of bearing orchard and I would suggest getting a good outfit if one had five acres of good apples, or less if the right man has it and the right kind of fruit.

If we go into a community where there are plenty of orchards that are well taken care of they have plenty of buyers for the fruit and as competition is the life of trade the fruit brings better prices; and as fruit from any certain locality where it is well grown and packed, and graded honestly, brings better prices in the markets, the buyers want such for the trade and they can sell it to better advantage than that from unknown parties, or from localities not known as apple sections. I understand Mr. Oakes has sold his crop at \$3.50 per barrel and if there were plenty more orchards around here that had been well sprayed and had good fruit he would likely have sold them for \$4.00 per barrel. As he has only just begun spraying and demonstrated that apples can be grown here successfully, even when he did not do a thorough job as we can see by the looks of the tops of the trees where the spray did not reach and the foliage is not the best, and some of the fruit scabby where they get the best fruit from unsprayed trees, so we may conclude that with better appliances and better work they can grow apples here that will compare favorably with those grown in the far west if we give the trees the attention they do out there. I feel certain that if this orchard had been sprayed another time late in the season, the last of July or first of August, for the late brood of the codling moth and leaf troubles that the fruit and foliage would be found sticking better.

On the hills generally we must do something with the orchards besides cultivating, and the sod mulch seems to be the best plan; it works well even in the bottoms, but then one must mulch instead of mowing the grass and taking it off as hay. One can cultivate if he wishes on land that will permit it, but I am in favor of mulching if properly done to conserve moisture and make fertility available.

Q. How far apart do you plant Rome Beauties?

A. Thirty to thirty-five feet on soil like this. (First bottom, Ohio river.) In the hills plant them twenty-five to thirty feet apart. Plant the rows around with the curvature of the hill, so that you can drive around the rows. Do not plant the rows up and down the hills. Plant the trees a little closer together in the rows than the distance between the rows. Say have the trees twenty-five feet apart in the rows and the rows thirty feet apart. If possible set the trees out in grass, as I think this will give the best results. I would recommend setting trees twenty-five by thirty instead of fifty or sixty by thirty. Set the trees fairly close on the hill land, as it will protect the soil and keep more moisture in the ground than if the trees were planted farther apart.

Q. Would not the evaporation from the trees be greater than the evaporation from the ground if the trees were planted farther apart?

A. It might be. That is a matter that must be found out by experimenting; but I would recommend planting the trees closer together.

Q. What would you do with trees where possibly one third of the branches are dead?

A. Trim up the trees, and try to get water-sprouts to fill up the vacant spaces.

Q. Do you cut the limbs off close to the trunk or leave a stub?

A. Cut the limbs close to the trunk is my advice. Some people say to leave a stub, but I would cut close to the trunk and then paint the wound.

Q. Do you spray for the foliage, and what do you use?

A. I do spray for the foliage. I think it makes the leaves stay on the trees longer, which causes the apples to stick on the trees longer, ripen up better and color up better. I spray from the middle to the last of July and use diluted Bordeaux mixture. About two to three pounds of blue vitrol to four or five pounds of lime, and a little arsenate of lead to the fifty gallons of water.

Q. Will it do to prune trees at any time in the year?

A. I prefer to do my pruning in the spring. When you cut the limbs off in the fall they check and crack badly if not painted. Pruning a tree in Summer when it is growing too fast may bring it into bearing earlier. I like to see the limbs down close to the ground. They may just as well be down to within a few feet of the ground, and bearing apples, as to have a vacant space there.

Q. Can you keep sheep in the orchard?

A. Keep the sheep out. If you want an orchard get rid of the sheep.

Q. How can you get rid of the rabbits in the orchard?

A. I keep the weeds and grass down in my orchard and am not troubled much with them. If I was I would kill them, or if I could not kill them myself I would hire someone to kill them for me. You can kill them, trap them, or place wire screens around the trees for protection.

Q. What are some good apples?

A. Grimes Golden and Jonathan for earlier varieties, and Rome Beauty and Rawles Janet for winter apples.

Q. How about the Ensee apple?

A. It has a fine quality, good size. The young trees bear when five or six years old. I believe that it is worthy of a trial. See that it is tested before you go into a new variety or you will get bit ninety-nine times out of one hundred.

Q. How about the winter Banana?

A. A fairly good apple. I would not advise anyone to put out an orchard of it. Do not go farther before experimenting with it.

Q. What of Stayman Winesap?

A. I do not know what it will do.

Q. What do you think of the Delicious?

A. Tastes real well. There are better for this region. Some in the Ohio valley are doing well. It is a fall apple here.

Q. What of the Hubbardston?

A. Too far south for it, I think. I do not think I would plant an orchard of it at present until I knew more about it. Too much of a fall apple.

Q. In spraying, some people use a pole with the fluid going through the pole. Others use a pole with the hose fastened to it. Which is best? It makes me tired to hold up a pole, with the hose fastened to it, for a day at a time.

A. By all means get a bamboo pole lined with brass or even aluminum, though that costs more, I believe. It is much lighter.

Chairman Waid said he thought they ought to hear from Mr. Ballou, who had charge of the spraying work in the orchard they had been inspecting.

Mr. Ballou said that the orchard had been sprayed to some extent before Mr. Oakes had told him that he sprayed quite differently from the way it was sprayed this year. In fact, he had sprayed very indifferently in comparison with the way it was sprayed this year.

Q. How much spray did you use to a tree, and what was the cost?

A. It ran from seven to eight gallons to a tree at each spraying. The cost of spraying the trees was from 25 cents to 30 cents per tree for three applications each. About 10 cents per tree for each spraying. This is for the material alone. The labor would be extra.

Q. Why are some of the apples here dropping so much?

A. Some of the apples were not sprayed. The apples in our sprayed plot have been dropping very little.

Chairman Waid then called upon Mr. Oakes, the owner of the orchard, for a few remarks.

Mr. Oakes stated that he had been fully converted to the spraying business. Last year he went through the orchard and found one little, knotty apple. He intended to grub out the entire orchard as soon as he could find a market for the timber. Last spring Mr. Ballou came around and asked him what seemed to be the trouble with the orchard. He told him that he thought it was the cold weather in the spring, which prevented the apples getting enough sap to develop. Mr. Ballou said he thought he could help things, a little; and, Mr. Oakes said, "you can look around and see the results. I am sorry now that Mr. Ballou did not get after me with a little hickory oil and make me get up into the trees and spray all of them

thoroughly. This orchard is past what I used to believe to be the age limit of a Rome Beauty orchard—thirty years. I now think that I can make it last as long as I live.”

Q. What will you do with your orchard now?

A. I propose to go through the orchard, thin out and trim up the trees, and if possible mulch them. I will not cultivate the orchard.

A MESSAGE FROM THE NORTH

By W. W. FARNSWORTH, Waterville

Whenever a body of men of kindred tastes, and following the same or similar avocations, come together for an interchange of experiences, great benefits are sure to follow.

Life is too short for the Horticulturist to secure the information necessary for the highest success through his own experience, and he who attempts it will find old age creeping on him before he has well mastered the rudiments.

The wise fruit grower is he who avails himself of the light which science and practise can give him, and by careful observation adapts these deductions to his individual needs.

Commercial and Domestic Horticulture have undergone great changes in the last score of years.

Twenty years ago nearly every farmer grew his own supply of fruit and usually had a surplus, which was thrown upon the market in any condition, in any package, at any price.

Unfortunately for the grower for home use only, but fortunately for the professional grower, these conditions have radically changed. The increased number of insect and fungous enemies and especially the advent of what Hale calls “That blessed San Jose scale” has given the field into the hands of the professional grower who is willing and able to equip himself with the necessary knowledge and appliances, and who will make a study of the business and make all others secondary or contributory.

One thing which has greatly retarded the progress of fruit growing, has been a tendency to copy blindly the methods of others or to follow dogmatic rules formulated by other fruit growers more or less successful.

We may and should learn much from others, but all plans and recommendations must be tested carefully and thoughtfully under our own conditions before being accepted as being applicable to our needs.

Prof. Roberts of Cornell when asked if certain dairy practices were commendable replied, ask the cow. And so when in doubt as to the wisdom of any contemplated method let us ask the trees.

In other words we must be close students and observers of our own business.

We can not lay down any ironclad rule of management which will apply to fruit trees under all conditions.

We must study the requirements of the tree.

Ask the tree what it requires and read its answer in the manner in which it responds to different treatments.

I believe there is a bright outlook for the Horticulturist in any part of Ohio who will push his business, and I believe that much of southeastern Ohio is particularly adapted to fruit growing.

A proper location is essential, but the proper man is even more so.

There are probably more fruit locations than fruit men.

To attain the highest measure of success and at the same time enjoy the greatest measure of satisfaction, we must like the business.

There are many little details which go to make the perfect orchard, and these will be attended to, only if we look upon each tree as a personal friend and acquaintance.

Individual practises in pruning have blazed a fairly plain trail which we may follow while studying how to do better, and observing the effects of different methods.

The science of spraying while yet in its infancy, has reached that stage where we stand on firm ground while we advance farther.

In the matter of feeding the tree, but little advance has been made because dame Nature has attended to that part of the work with but little of our help.

It is high time for us to begin to cooperate with her however. Nature produces fruits unaided, but with man's assistance she produces much better crops of much better fruits.

We should study the requirements of the tree and aim to secure the necessary food and moisture, by those means which under our conditions, will accomplish the end in the cheapest and most effective manner.

We can not say that all must cultivate, neither can we say that all should mulch. Conditions must govern.

Possibly the most general rule which can be given, is that all must spray, and spray thoroughly, if they wish to succeed.

But we can not say that all shall spray alike or that the same grower should spray two seasons alike.

The fruit grower on the "Sun Kissed" hills of Ohio must face the problem of moisture and fertility in a different manner from which we meet it on our stronger level lands.

The amount of fertility required to produce a dollar's worth of fruit, is much less however than that required to produce a dollar's worth of grain.

The necessary humus must usually be grown either in the orchard itself or on land adjoining.

Probably this will need to be supplemented by the use of commercial fertilizers although in some instances, the addition of sufficient humus, may render available a sufficient amount of the mineral elements already in the soil. A safe rule for the novice is to adopt the practises of the most successful growers, whose conditions are similar, and then not follow them blindly, but search out the reason for everything and always try to improve. Then the question of marketing the fruit is of great importance. People are more particular about the quality of their fruits than of most other products. While a bushel of the finest wheat may not sell in the market for more than 25 to 30 percent more than a bushel of number 3 yet a bushel of fancy peaches will bring three or four times as much as a bushel of the third grade. The masses are coming to recognize fruit as a luxurious necessity and want it not only of good quality but attractive in appearance, and he who places on the market just such an article as he himself would like to buy were he purchasing, will have no trouble in getting and keeping customers. The manner of marketing as well as the varieties to plant will depend upon conditions. If you have good shipping facilities to a good market and are making fruit growing your main business, you will do well to plant a succession of varieties and arrange to supply grocers

or consumers during the entire season, thus securing a good trade and distributing the labor of harvesting and marketing over a long season. If however you have not these advantages, or if fruit growing is but a side issue with you, you will do better to grow but few varieties and sell at wholesale.

To recapitulate. Don't go into the fruit business simply because you think there is money in it. You must love it to succeed. Take a personal interest in every tree and plant. Cooperate with nature to feed and water the tree in the cheapest way you can and still secure the greatest possible amount of fine fruit, for the largest number of years. Prune intelligently or in other words be able to give a reason for every limb you cut off. Spray diligently and know what every application is for and examine carefully to see if it accomplishes the desired end.

Do not plan too large an acreage. Market in accordance with the Golden rule and remember that a pleased customer is the best advertisement.

INDEX.

Acid mineral elements in animal nutrition, the.....	25
Acidosis,.....	26, 41
Adams Fund, account with,.....	xii
Agricultural production in Ohio, centers of,.....	Circular 100
Agronomy, work of department of,.....	xvi
Ammoniacal solution of copper carbonate, formula for,.....	359
Animal husbandry, work of department of,.....	xvii
Apple culture in Ohio.....	Bul. 217, pp 527, 559
Apple culture, revival of,.....	xxii
Apples for northern Ohio,.....	535
Apples for northern Ohio,..	536
Apple scab fungus cause of apple failure.....	549
Apples, storage rots of,.....	362
Apples, the time to spray,.....	545
Apples, thinning,.....	547
Appropriations, State,.....	vxiii
Arsenite of soda for potatoes, formula for,.....	592
Bacterial disease of oats,.....	91
Balance between inorganic acids and bases in animal nutrition, the, ...	Bul. 207, pp, 23-52
Basic mineral elements in animal nutrition, the,.....	26
Blade blight of oats, the,.....	Bul. 210
Board of Control, report of,.....	v
Bones, malnutrition of the,.....	35
Botany, work of department of,.....	xviii
Bordeaux mixture, formula for,.....	357, 358, 545, 590
Bran disease,.....	34, 37, 39, 47
Buildings needed,.....	vi
Bursar, report of,.....	xi
Centers of agricultural production in Ohio, the,.....	Circular 100
Chemistry, work of department of,.....	6, ix
Chinch bug, how to fight the,.....	664
Cooperation, work of department of,.....	xix
Cooperative dairy work,.....	Circular 99
Cooperative experiments, work of department of,.....	Circular 97
Copper compounds as sprays,.....	359
Corn, are we growing the best varieties?.....	663
Corn: bare, vs. filled tips.....	223
Corn: effect on seed of previous environment,.....	229
Corn, fertilizers on, at Germantown.....	14
Corn: germination box as index to high yielding ears,.....	231
Corn: heavy vs. light seed ears,.....	226
Corn: importance of adaptability,.....	232
Corn: importance of hill stand.....	234
Corn judging: studies of prominent ear characters in their relation to yield,.....	Bul. 212, pp, 212-236

Corn: relation of length of ear to yield,.....	214
Corn: relation of shape of ear to yield,.....	219
Corn: rough vs. smooth-dented ears,.....	225
County experiment farms, law authorizing,.....	vii
County experiment farms, what they may accomplish,.....	xxiv
County fair exhibits,.....	xix
Dietary, the human,.....	40
Director, report of,.....	xvi
Do southwestern Ohio soils need lime?.....	661
Diseases of Ohio plants:—	
Alder, ...	367
Alfalfa, ...	367
Apple, ...	368
Apricot, ...	375
Ash, ...	376
Asparagus, ...	376
Azalia, ...	376
Barberry, ...	376
Barley, ...	377
Bean, ...	377
Beech, ...	378
Birch, ...	378
Beet, ...	378
Begonia, ...	378
Blackberry, ...	379
Blue-grass, ...	379
Broom-corn, ...	379
Buckwheat, ...	380
Cabbage, ...	380
Cauliflower, ...	380
Calla, ...	382
Carnation, ...	382
Canna, ...	382
Cantaloupe, ...	382
Carrot, ...	383
Cedar, ...	383
Catalpa, ...	383
Celery, ...	384
Cherry, ...	386
Chess, ...	387
Chestnut, ...	387
Chrysanthemum, ...	388
Clover, ...	388
Corn, ...	390, 456
Cowpea, ...	392
Crabapple, ...	392
Crocus, ...	392
Cucumber, ...	392
Currant, ...	395
Dewberry, ...	396
Eggplant, ...	396
Elm, ...	397
Emmer, ...	397
Fig, ...	397
Filbert, ...	397
Flax, ...	397
Forest seedlings, ...	398
Ginseng, ...	398
Golden seal, ...	398
Gooseberry, ...	398
Gourd, ...	399
Grape, ...	399
Grasses, ...	401
Hazlenut, ...	401
Hemlock, ...	401
Hickory, ...	401
Hollyhock, ...	402
Horse-chestnut, ...	402
Horseradish, ...	402
Hydrangia, ...	402
Iris, ...	403
Ivy, ...	403
Japan creeper, ...	403
Larch, ...	403
Lemon, ...	403
Lettuce, ...	404
Lily, ...	407
Locust, ...	407
Lupinus, ...	407
Mangel-wurzel, ...	407
Maple, ...	407
Millet, ...	408
Mulberry, ...	408
Muskmelon, ...	408
Mustards, ...	409
Oak, ...	410
Oats, ...	411
Oat -grass, ...	413
Onion, ...	413
Orange, ...	416
Orchard-grass, ...	416
Palm, ...	416

Pine, ...	429	Soybean, ...	440
Plum, ...	429	Spinach, ...	441
Poplar, ...	431	Snap-dragon, ...	441
Potato, ...	431	Squash, ...	441
Primula, ...	436	Solomon's Seal, ...	441
Privet, ...	436	Spruce, ...	441
Pumpkin, ...	436	Strawberry, ...	441
Quince, ...	436	Sugar-beet, ...	441
Radish, ...	437	Sweet-potato, ...	443
Pea, ...	416	Sweet-corn, ...	443
Peach, ...	418	Sycamore, ...	443
Pear, ...	427	Timothy, ...	444
Pelargonium, ...	428	Tobacco, ...	444
Peony, ...	428	Tomato, ...	447
Peppers, ...	428	Turnip, ...	451
Persimmon, ...	428	Verbena, ...	451
Phlox, ...	428	Veronica, ...	451
Rape, ...	437	Vetch, ...	451
Raspberry, ...	437, 456	Vinca, ...	451
Red-top, ...	438	Violet, ...	451
Rose, ...	438	Virginia creeper, ...	451
Rutabaga, ...	439	Walnut, ...	452
Rye, ...	439	Watermelon, ...	452
Salsify, ...	440	Wheat, ...	452
Sorghum, ...	440		

Entomology, work of department of, ...	xxii
Enzymatic diseases of plants, ...	332
Essentials of successful field experimentation, ...	Circular 96
Experiments, cooperative, work of department of, ...	Circular 97
Fairs, state and county, exhibits at, ...	Circular 101
Farm management investigations, ...	xix
Farm equipment, minor items of, ...	Circular 98
Fence posts, black ash, ...	619, 630, 633
Fence posts, catalpa, ...	617, 626, 632
Fence posts, chestnut, ...	619, 629, 633
Fence posts, honey-locust, ...	619, 630
Fence posts, mulberry, ...	617, 625, 632
Fence posts, oak, ...	619, 630, 633
Fence posts, osage orange, ...	615, 620, 632
Fence posts, red cedar, ...	616, 622, 632
Fence posts, sassafras, ...	619
Fence posts, white cedar, ...	617, 625, 632
Fence posts, yellow locust, ...	616, 622, 632
Fence posts, setting top or bottom up, ...	613
Fence posts, see post timbers, ...	
Fertilizers on corn and wheat at Germantown, ...	14
Fertilizers on potatoes, ...	600
Fertilizers on tobacco, ...	1
Fertilizing pastures, ...	664
Field experimentation, essentials of successful, ...	Circular 96
Financial report, ...	xi

Forage crops for emergencies,.....	661
Forcing house, soil treatment in,.....	342
Forest conditions in Ohio, third annual report on, ...	Bul. 211, pp. 169-212
Forest conditions in Greene county,.....	191
Forest conditions in Washington county,.....	198
Forest conditions in Wayne county,.....	180
Forest survey, a,.....	180
Forest work, cooperation,.....	171
Forestry, work of department of,.....	xx
Formaldehyde gas treatment, formula for,.....	365
Formaldehyde solutions,.....	360
Fruit trees, protection from rodents,.....	53
Fruit trees, purchasing,.....	612
Germantown test-farms, the,.....	vi
Grafting wax, recipe for,.....	70
Handbook of the diseases of cultivated plants in Ohio,.....	Bul. 214, pp. 307-456
Harvest mites,.....	660
Hatch Fund, account with,.....	xi
Horticulture, work of department of,.....	xxii
Human dietary, the,.....	40
Illustrative exhibits at state and county fairs,.....	Circular 101
"Jiggers"	660
Leaf-spot and shot-hole effects,.....	312
Lime, effect of on tobacco,.....	7
Lime for spraying purposes,.....	592
Lime-sulphur mixture, formula for,.....	69
Meteorological summary,.....	Bul. 220 pp. 641-659
Methods for estimation of inorganic phosphorus,.....	Bul. 215, pp. 459-489
Maintenance of fertility, the,.....	Bul. 206, pp. 1-21
Malnutrition of the bones,.....	35
Mineral acids and bases in foods,.....	43
Mineral elements in animal nutrition, the,.....	661
Minor items of farm equipment,.....	Circular 98
Nutrition, work of department of,.....	xxii
Oats, blade blight of,.....	91
Osteomalacia, ...	35, 37, 37
Osteoporosis, ...	38
Onions, storage rots of,.....	363
Orchard, location of the,.....	530
Orchard planting,.....	534
Orchard pruning, ...	536
Orchard, soil for the,.....	532
Orchards, foliage disease of,.....	347
Orchards, sort diaeases of,....	346
Orchard trees, wound infection of,.....	349
Orchard spraying,..	538
Orchards renewal of old,.....	537
Parasitic fungi, concerning,.....	320
Pastures, care of,.....	664
Pasture in swine feeding,.....	79
Personnel, ...	xxvii
Phosphorus in certain food stuffs,.....	476

Phosphorus, inorganic, methods for estimation of, In animal tissues,.....	481
Phosphorus, inorganic, methods for estimation of, in vegetable substances, ..	460
Phosphorus, relation of to development of muscle in swine,.....	262
Plant diseases,.....	307
Plant diseases and atmospheric conditions,.....	353
Plant diseases transmitted in seed,.....	333
Potato growing industry in Ohio, status of the, ...	Bul. 218, pp. 561-603
Potatoes, Bordeaux mixture for,.....	590
Potatoes, classification of,.....	593
Potatoes, effect of treatment on vitality of seed, ...	600
Potatoes, examine seed for dry rot,.....	663
Potatoes, fertilizing,.....	563, 600
Potatoes, fusarium wilt in,.....	601
Potatoes, insecticides for,.....	591
Potatoes, late grown, vs. common seed,.....	597
Potatoes, northern grown, for seed,.....	565
Potatoes, quantity of seed per acre,.....	570
Potatoes, seed selection,.....	578
Potatoes, small, for seed,.....	586
Potatoes, storage of seed,.....	567
Potatoes, storage rots of,.....	363
Potatoes, "Sun-sprouted" seed, ...	568
Potatoes, rotations for,.....	562
Potatoes, seasonal report on, 1909,.....	597
Potatoes, spraying,.....	589
Potatoes, treating for scab,.....	599
Post timbers, estimating value of, ...	630
Post timbers, relative durability of, ...	Bul. 219, pp. 605-639
Post timbers, time of cutting,.....	907
Poultry, does farm poultry pay?.....	662
Press bulletin reprints,.....	660
Produce Fund, account with,.....	xiv
Protection of fruit trees from rodents,.....	Bul. 208
Pruning fruit trees,.....	536
Publications of the year,.....	xxvi
Purchasing seeds and fruit trees,.....	662
Rainfall and temperature in Ohio, mean summer,.....	354
Rations for fattening swine, ...	Bul. 209
Rickets, ...	33, 37, 38
Rodents, protection of fruit trees from, ...	53
Root diseases of orchards,.....	346
Root nodules,.....	329, 389
Rot disease comes in storage, ...	361
Seed potatoes, dry rot in,.....	663
Seeds, purchasing,.....	662
Seed treatment for plant diseases,.....	338
Soil investigations, ...	xxiii
Soil infesting parasites of plants,.....	339
Soil treatment for plant disease prevention,.....	344
Soil treatment in the forcing house,.....	342
Southwestern Ohio soils, do they need lime?.....	661

Soybeans for swine,.....	75
Specific effects of rations on the development of swine,.....Bul. 213, pp. 237-305	
Sprayers, compressed-air,.....	516
Sprayers, traction-power,.....	511
Spraying, cost of,.....	505
Spray accessories, list of,.....	505
Spraying demonstration in Washington county,.....	547
Spraying, lime for,.....	592
Spraying for prevention of plant diseases, philosophy of,.....	357
Spraying orchards,.....	538
Spraying outfits, description of,.....	508
Spraying to kill weeds,.....	Circular 102
Spray nozzles, manufacturers of,.....	500
Spray pump, factors to be considered in choosing,.....	492
State appropriations,.....v, xiii	
Statistics of agriculture in Ohio,.....	Circular 100
Swine, effects of rations on development of,.....	239
Swine, rations for fattening,.....	71
Tankage for swine,.....	75
Temperature and rainfall in Ohio, mean summer,.....	354
Timber rots and timber preservation,.....	351
Tobacco, experiments with fertilizers on,.....	1
Weeds, spraying to kill,.....	Circular 102
Wheat, fertilizers on at Germantown,.....	14
Wilt diseases of plants,.....	314

UNIVERSITY OF ILLINOIS-URBANA



3 0112 048264524